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TELEVISION SIGNAL CODING

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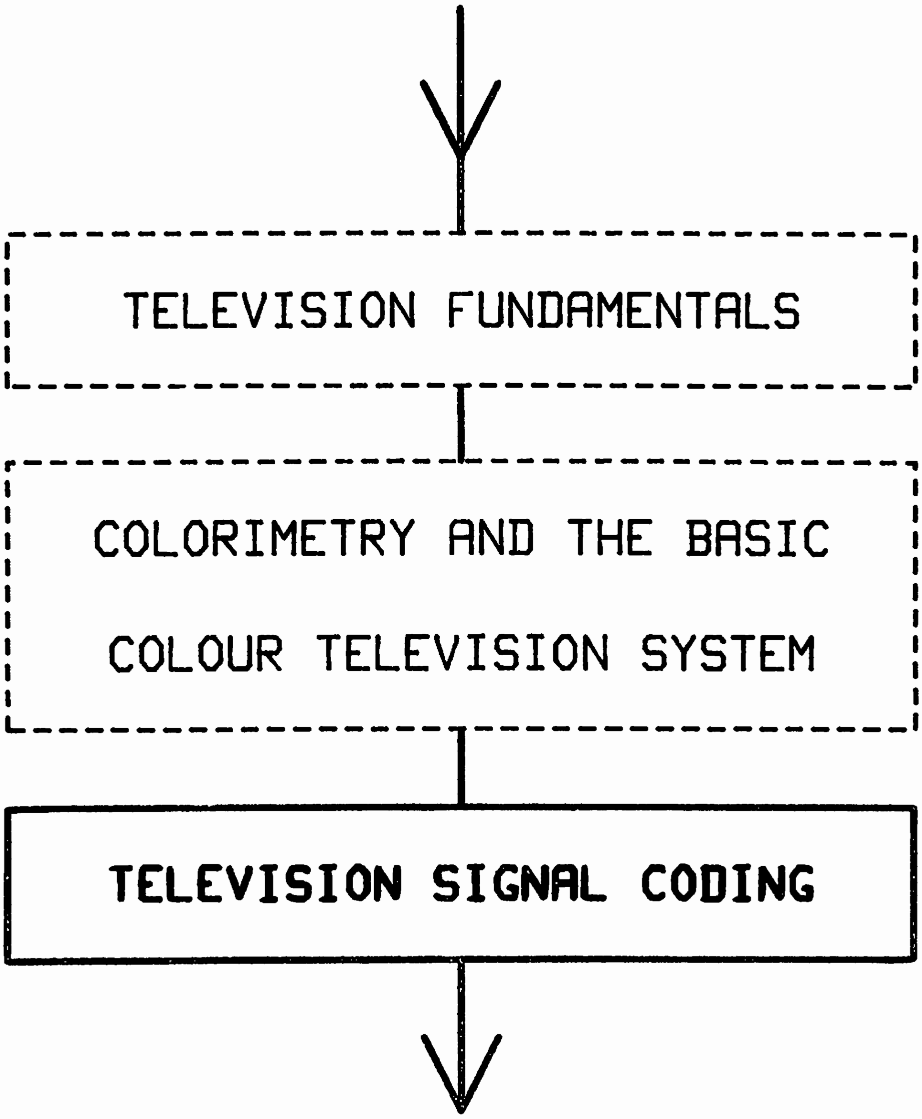
TELEVISION FUNDAMENTALS
COLORIMETRY AND THE BASIC COLOUR TELEVISION SYSTEM
TELEVISION SIGNAL CODING

SUBJECT STRUCTURE

This package is the third and final part of the Television Principles Module.

The first package in the module examined Television Fundamentals, and developed the basic monochrome television system. It also explained the methods used to recover the d.c. component of the video signal.

The second package in the module examined the principles of Colorimetry, a necessary part of a good understanding of colour television. It then introduced the method adopted to combine the colorimetry principles with the monochrome television system to establish a Basic Colour Television System. The inherent characteristics of using a non-linear display tube were also introduced.

This package now examines methods used in Television Signal Coding to code the colour difference signals required by the basic television system and combine them with the monochrome television signal to produce a Composite Coded Video Signal. Whilst the main emphasis is on the British PAL system of coding, the NTSC system is examined in the first instance, and a brief description of the SECAM method of coding is also included.

AIMS OF THE PACKAGE

The broad aims of this package are:-

1. To illustrate some possible methods of coding the colour difference signals.
2. To explain the principles of Suppressed Carrier Modulation.
3. To examine in detail the characteristics of Suppressed Carrier Modulation, using vectors to analyse the chrominance component of Colour Bars.
4. To identify the characteristics and problems associated with the composite coded video signal.
5. To estabish the types of distortions which affect the coded video signal.
6. To highlight the principles of the NTSC, SECAM and PAL systems of coding.
7. To analyse the detailed operation of the PAL system.
8. To examine the reasons for the choice of the PAL subcarrier frequency.

PACKAGE STRUCTURE

This package consists of two units. This unit contains the theory associated with the coding of a colour television system, and the other unit contains details of various practical demonstrations for you to undertake during your study.

The theory unit is divided into nine sections. The first eight sections cover the subject aims as detailed on the previous page, and the final section contains revision notes on the whole package.

STUDY GUIDE

This package is self-paced, but as a guide you should expect to complete it in about three half day periods.

As you read through the text, you will find reference to a number of practical investigations for you to undertake, and a number of questions for you to answer.

When a practical demonstration or investigation is necessary, the theory unit will direct you to the appropriate activity in the practical unit. You should then leave the theory unit and undertake the practical activity as instructed. If however, the practical equipment is not available at this time, you may continue with the theory unit, but the practical should be undertaken as soon as possible.

Throughout the package you will find a number of questions to answer, or waveforms to draw. Answers to these Continuous Progress Questions **(CPQs)** found in the Theory Unit should be written on a separate sheet of paper which your supervisor can then use to assess your progress through the package. Spaces will be found within the practical unit for you to answer some of the questions or draw the waveforms as required. If you experience any difficulty in answering any of the questions you should consult your supervisor.

The concluding section of the theory unit contains revision notes. These are only brief notes, and are intended for revision use only after you have completed the package.

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SECTION 1

METHODS OF CODING

SECTION 1 METHODS OF CODING.

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1. METHODS OF CODING

1.1 CODING PRINCIPLES

The basic colour television requirements established in the previous package involve the transmission of the colour difference signals (R - Y) and (B - Y), in addition to the luminance signal. It would not be possible to combine the signals by pure addition at base band because of the problems encountered with separation, so some form of coding of the colour difference signals has to be undertaken. MODULATION is the form of coding used in all the three broadcast systems (NTSC, SECAM and PAL).

The block diagram symbol for a modulator is shown in Figure 1-1.

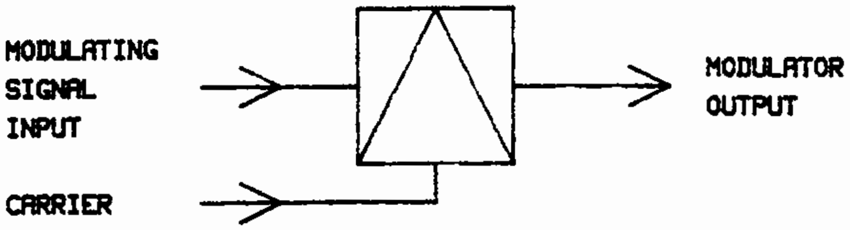

Figure 1-1. Symbolic Representation of a Modulator.

The type of modulation (e.g. A.M. or F.M.) used will depend on the systems. A basic block diagram of the coding process could be drawn as shown in figure 1-2.

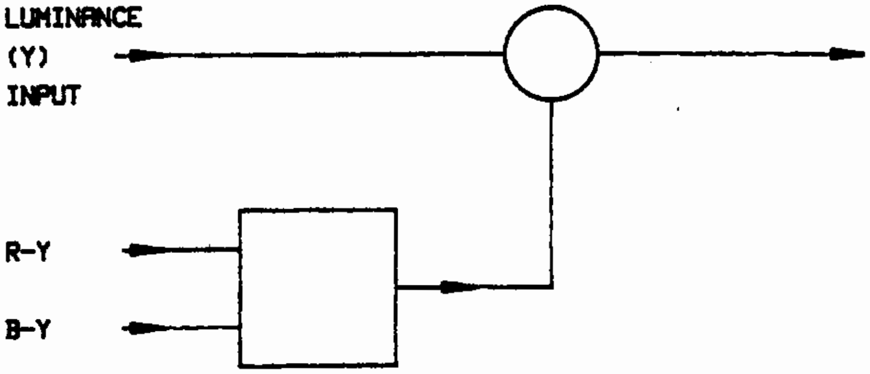

Figure 1-2. A Possible Block Diagram of a Coder.

CPQ1

With reference to figure 1-2, write down as many reasons as you can why the system as shown would be difficult to construct and to operate.

*

When comparing the modulator used in figure 1-1 with that as shown in figure 1-2, one reason for a difficulty should be apparent, i.e. the modulator in figure 1-2 has two inputs. To overcome this problem, the SECAM system adopts one solution, and the NTSC and PAL systems adopt another.

1.2 THE SECAM SOLUTION

The SECAM system overcomes this problem by time division multiplexing, or switching in turn between inputs. The switching takes place at line rate, so that during one line the modulated (R - Y) signal is added to the luminance and on the next line modulated (B - Y) is added. Figure 1-3 shows the block diagram modified for SECAM coding.
A one line delay must also be incorporated in the decoder to ensure that both colour difference signals are available at any time. Some form of signal must be sent to the decoder to ensure separation of the correct colour difference signal.

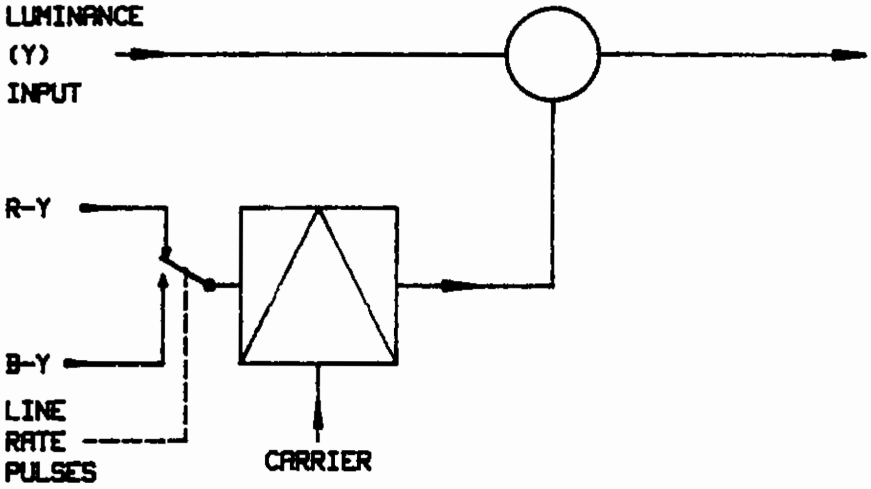

Figure 1-3. Simplified Schematic of the SECAM System of Coding.

1.3 THE NTSC SOLUTION

The NTSC method of transmitting two colour difference signals is to provide two modulators in the coder. The type of modulators used, however, must be capable of having their outputs combined prior to addition to the luminance signal and then separated in the decoder.
Figure 1-4 shows the simplified block diagram for the NTSC system.

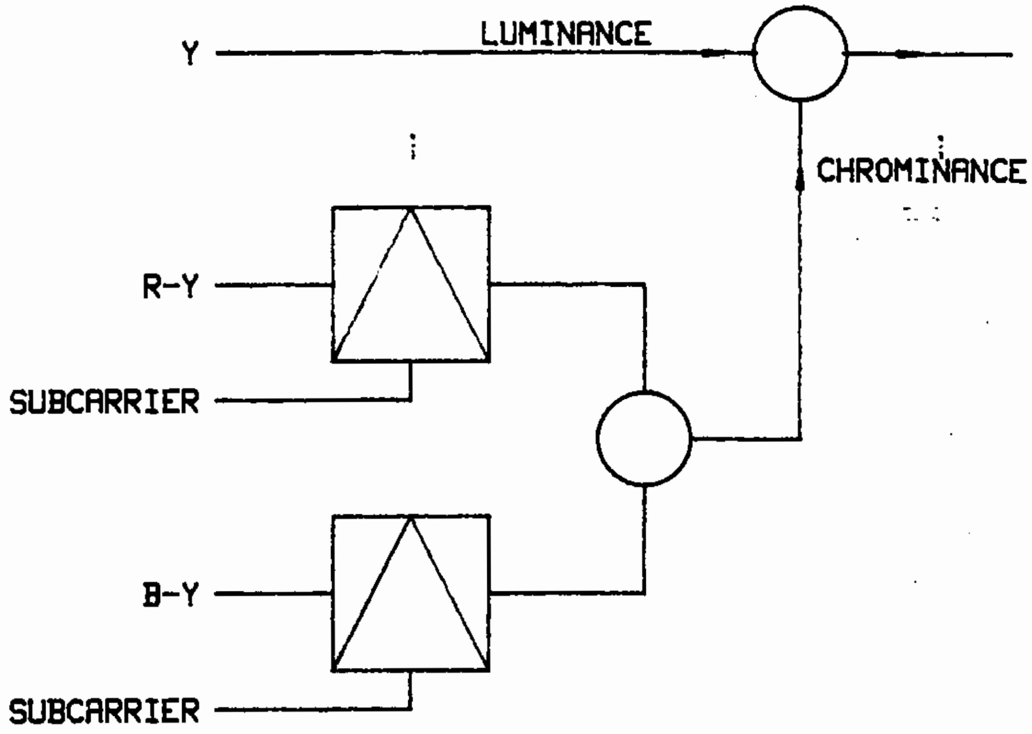

Figure 1-4. Simplified Schematic of the NTSC system of Coding.

The carrier used in a colour difference signal coder modulator is known as the COLOUR SUBCARRIER (C.S.C.).

After the output of the two modulators have been combined, this signal is known as the CHROMINANCE signal.

The luminance and chrominance signals are then combined to produce the composite CODED video signal.

1.4 FREQUENCY OF THE SUBCARRIER

Two other problems that you may have identified in your answer to CPQ1 are those of compatability and interference with the monochrome signal. Both of these problems are functions of the frequency chosen for the subcarrier. It is also found that the eye is not sensitive to fine detail in colour, so this fact may be utilised to reduce the bandwidth of the colour difference signals to 1.3MHz.

To completely avoid interference between the chrominance and luminance signals, the modulators' carrier frequency may be chosen so that the resulting subcarrier and its associated side bands lie outside the video spectrum. If the luminance spectrum extends to 5.5 MHz and the bandwidth of the colour difference signals is 1.3MHz, then subcarrier frequencies of say, 7.0 MHz and 10MHz could be used. This would give an overall spectrum for the video signal as shown in figure 1-5. This, however, would not be acceptable as sufficient space is not available between the transmitted RF channels which have an overall bandwidth of only 8MHz.

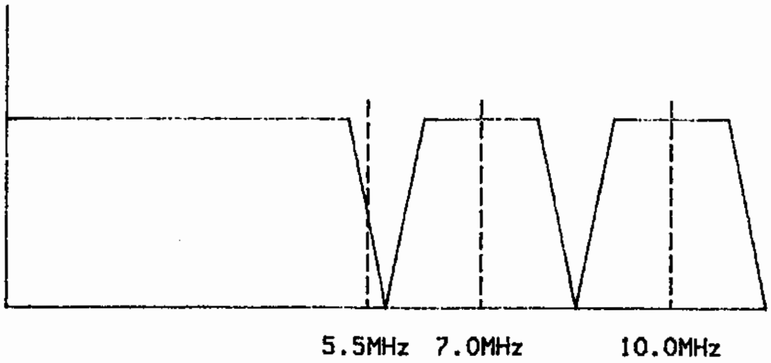

Figure 1-5. The Effect of Modulating out of Base Band.

Broadcast colour television systems use subcarrier frequencies which ensure that all the information lies within the video spectrum.

CPQ2

Working on the assumption that the video spectrum extends to 5.5 MHz and the band width of the colour difference signals is 1.3 MHz, deduce a suitable frequency for the subcarrier and draw a frequency spectrum of the combined signal.

As soon as we include the subcarrier and its associated side bands within the video spectrum, the problem of interference occurs. The amount of interference produced will depend upon the type of modulation and the exact frequency of the subcarrier that is chosen.

1.5 TYPES OF MODULATION

The two main types of modulation available may be broadly split into :-

(i) Frequency Modulation (F.M.)

(ii) Amplitude Modulation (A.M.)

The SECAM system uses F.M. whereas the NTSC and PAL system use A.M.

CPQ3

List the basic characteristics of F.M. and A.M. with particular reference to bandwidth and noise.

1.6 FREQUENCY MODULATION

The SECAM system chose to use frequency modulation. In general terms, it can be stated that frequency modulation has the advantage of better quality of reproduction, being less prone to interference, but this is at the expense generally of the increased bandwidth required. F.M. is characterised by a constant amplitude of carrier (subcarrier in the coding context). Since the output of the modulator is not to be directly transmitted, the question of power efficiency is of no concern, but the constant amplitude of the subcarrier, even with zero modulating colour difference signal, will produce objectionable interference on the luminance signal.

1.7 AMPLITUDE MODULATION.

NTSC and PAL systems both amplitude modulate the subcarrier. Full amplitude modulation would still suffer from the same problem as F.M., namely a constant amplitude residual carrier even with no modulating colour difference signal.

1.8 OBSERVATION

Have an objective look around you now and notice how desaturated most of the scene is, particularly if you ignore artificially generated colours, such as oscilloscope traces, L.E.Ds etc. and concentrate on a natural scene,

1.9 AMPLITUDE MODLATION WITH SUPPRESSED SUBCARRIER.

If the carrier of an A.M. signal is suppressed, then, for no modulating signal, there will be no output. This will consequently reduce the interference by the chrominance signal on the luminance signal to zero for a monochrome picture where there are no colour difference signals.

If a typical colour television picture is analysed, it will be found that, in general, the level of chrominance is very low, i.e. most pictures are fairly desaturated, this then would only produce low levels of subcarrier to interfere with the luminance.

SECTION 2

SUPPRESSED CARRIER AMPLITUDE MODULATION

SECTION 2. SUPPRESSED CARRIER AMPLITUDE MODULATION

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2. SUPPRESSED CARRIER AMPLITUDE MODULATION

2.1 FREQUENCY COMPONENTS OF SUPPRESSED CARRIER MODULATION

In conventional A.M., the amplitude of the signal for 100% modulation is varied from its steady state value with no modulating signal to a maximum of twice this amplitude and a minimum of zero as the modulating signal is varied. This is shown in figure 2-1.

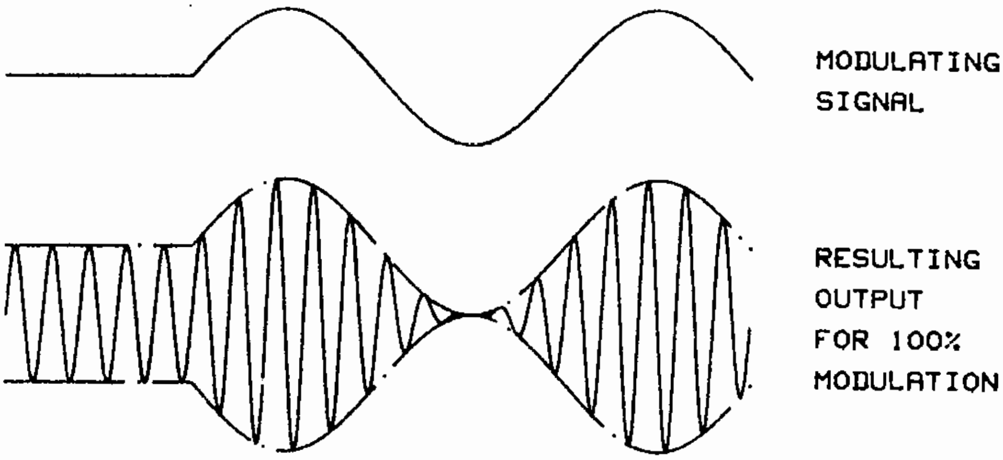


Figure 2-1. Amplitude Modulation Waveform.

The resulting carrier waveform may be represented either vectorially or by analysis of the spectrum of its individual frequency components, as shown in figure 2-2.

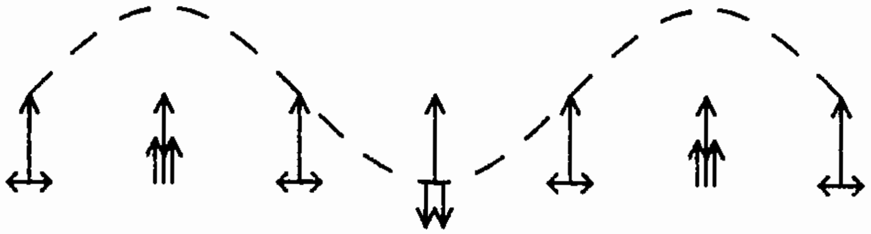


Figure 2-2(a). Vector representation of A.M.

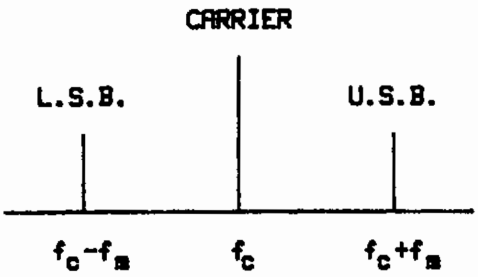


Figure 2-2(b). Spectrum representation of A.M.

Suppressing the carrier in A.M., has the effect of

(a) reducing the signal to zero for no modulating voltage, and (b) doubling the frequency of the resulting envelope. This is shown in figure 2-3 and figure 2-4.

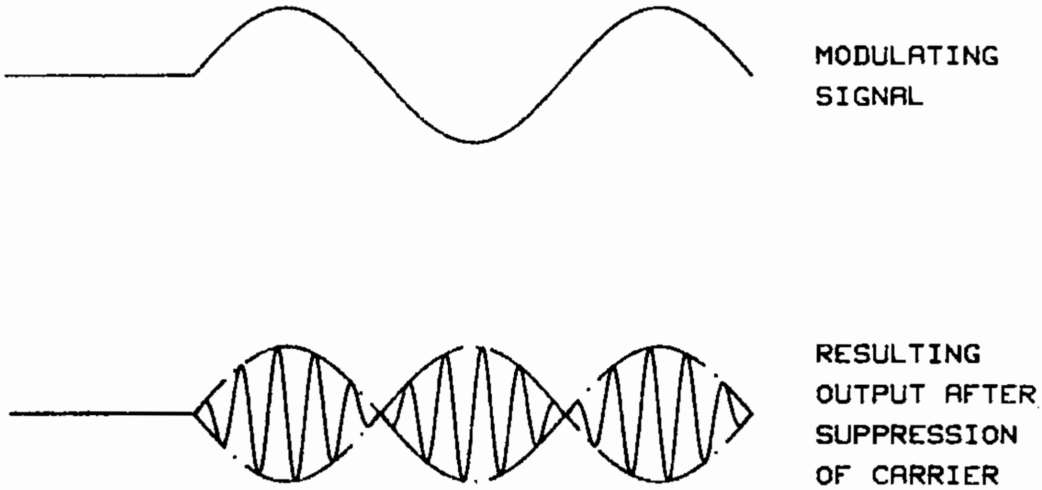


Figure 2-3. Suppressed Carrier A.M. Envelope

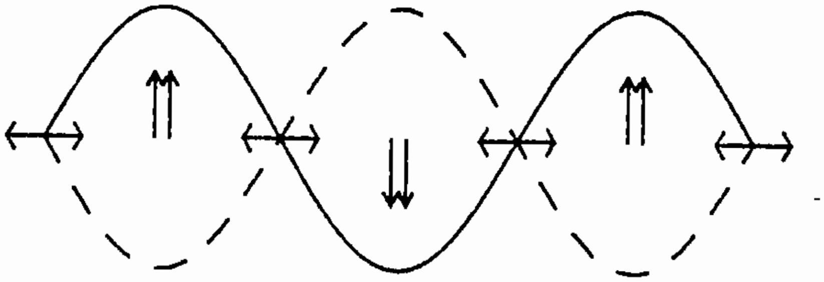
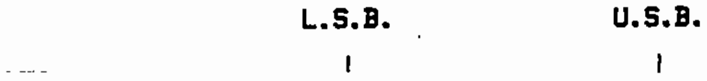


Figure 2-4(a). Vector Representation of Suppressed Carrier Modulation



The examples shown so far are for a single frequency sine wave modulating signal. Colour difference signals could however contain frequency components up to 1.3 MHz. This would modify the frequency spectrum to that shown in figure 2-5.

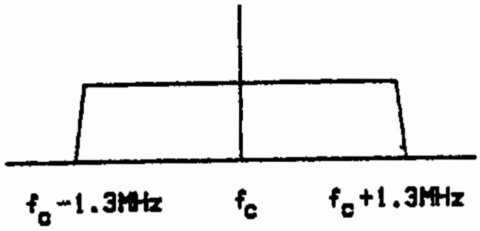


Figure 2-5. Frequency Spectrum of A.M. Carrier Modulated up to 1.3 MHz.

If the carrier in this example were to be suppressed, the spectrum would be modified to that shown in figure 2-6.

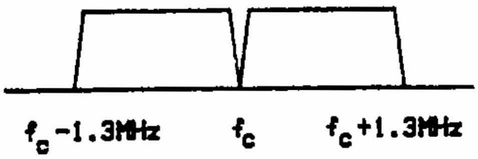


Figure 2-6. Spectrum of Suppressed Carrier Modulated up to 1.3 MHz.

In practice, it would be difficult to suppress the carrier frequency using a filter, though it would be possible to add carrier in anti-phase to achieve suppression. This is not a convenient method and an alternative design of modulator is used.

2.2 CHARACTERISTICS OF SUPPRESSED CARRIER MODULATION.

If the waveform of the suppressed carrier A.M. signal is examined closely, it will be seen that the instantaneous PEAK-PEAK amplitude of the waveform is directly (X 2) proportional to the instantaneous value of the modulating signal. This is shown in figure 2-7. It follows from this that there will be no carrier present for zero modulating signal.

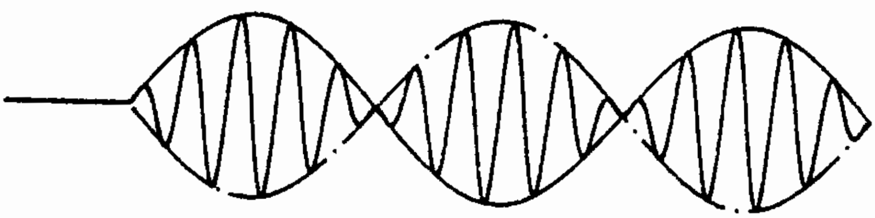


Figure 2-7. Suppressed Carrier A.M. Envelope.

Until now, only a sinusoidal modulating signal has been considered. The colour signal difference signals that will be the modulating signal in the colour television coders are, however, far from being sinusoidal. It is more convenient to think of them as being low frequencies or better still d.c.

Consider a colour difference waveform, as shown in figure 2-8.

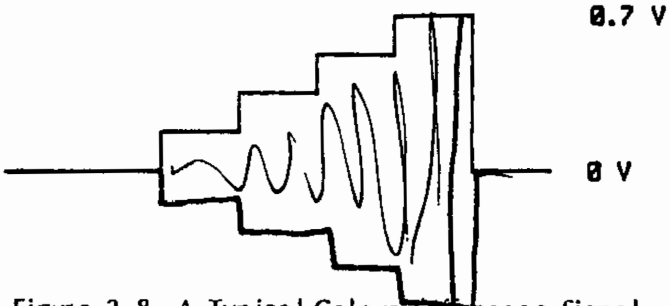


Figure 2-8. A Typical Colour Difference Signal.

CFQ4.

Draw a waveform that you would expect from a suppressed carrier modulator fed with the waveform shown in figure 2-8 as is modulating signal input. Show about two cycles of sub-carrier for each step.

2.3 PRACTICAL VALUES OF (R - Y) AND (B - Y)

You have now established what the subcarrier waveform should look like for a colour difference signal, which extends from 0.7 volts to zero in four steps. But what is the range of practical values of (R - Y) and (B - Y) that we are likely to encounter?

The normal maximum amplitude of a non-composite video signal is 0.7V. This level also applies to the R, G and B signals separately. Rather than use 0.7V as a maximum signal level, it is more convenient to work effectively in T units. This involves representing 0.7V as one signal unit.

In order to assess the requirements of the modulators, we first have to establish what input levels we will need to handle. The most extreme cases possible are those of the three 100% saturated primary colours (red, green and blue), the three complementary colours (yellow, cyan and magenta) together with black and peak-white.

CPQ5.

Complete the table of values of colour difference signals shown below. Use the established formula Y = 0.3R + 0.59G + 0.11B and work in signal units, i.e. as the colours are 100% saturated, the values of R, G and B will either be 1 or 0. If you are at all doubtful about this, attempt the question on a separate piece of paper and ask your supervisor to check your results before copying them into the table below.

Colour	R	G	B	Y	R–Y	B–Y
White	1	1	1	1	0	0
Yellow	1	1	0	89	·11	-0·89
Cyan	0	1	1	·70	–·70	·3
Green	0	1	0	·59	–0·59	-0·59
Magenta	1	0	1	·41	·59	·59
Red	1	0	0	·3	·7	-0·3
Blue	0	0	1	·11	-0·11	·89
Black	0	0	0	0	0	0

What are the main points to note from this table?

(a) With the given order of colours, the value of the Y signal decreases in steps from 1 to 0.

(b) The values of R, G and B for the colours in the order given form a pattern.

(c) The amplitude of the colour difference signals is zero for monochrome (black and white). Check this is true for a grey signal, e.g. R = G = B = 0.5.

(d) The range of the amplitude of the colour difference signals varies from -0.7 to +0.7 for (R - Y) and from -.89 to +.89 for (B - Y).

CPQ6.

On a sheet of graph paper, draw to scale the waveforms expected for the Y signal and the two colour difference signals.

2.4 THE MODULATED WAVEFORM

It has now been established that the values of colour difference signals could be negative. Suppressed carrier modulation has only been considered for positive values of the modulating signals so far. What happens if the signal is negative?

Referring to your answer for CPQ4, it was shown that, for a reduction of amplitude of colour difference signals, the amplitude of the subcarrier waveform reduced until the zero condition was reached. In a practical suppressed carrier modulator, when the modulating signal goes negative, a phase inversion (180° phase shift) takes place.

The two main characteristics of double sideband suppressed carrier modulation that are applicable to the coding process are:-

(a) The amplitude of the envelope is directly proportional to the amplitude of the modulating signal.

(b) The phase of the modulated signal is dependent on the polarity of the modulating signal.

These characteristics can now be confirmed by examining the practical waveforms.

Turn to your practical unit, and after reading the introduction, undertake practical investigations **LRC 1** and **LRC 2.**

2.5 METHODS OF MODULATION

Early coders used ring modulators to provide the suppressed carrier A.M. signal, but another approach to the subject is to consider the modulator as switch. The alternate positive and negative half cycles of the carrier may be used to switch the modulating signal between its normal value and its inverted version. A simplified block diagram of this type of modulator is shown in figure 2-9 and its associated waveforms are shown in figure 2-10.

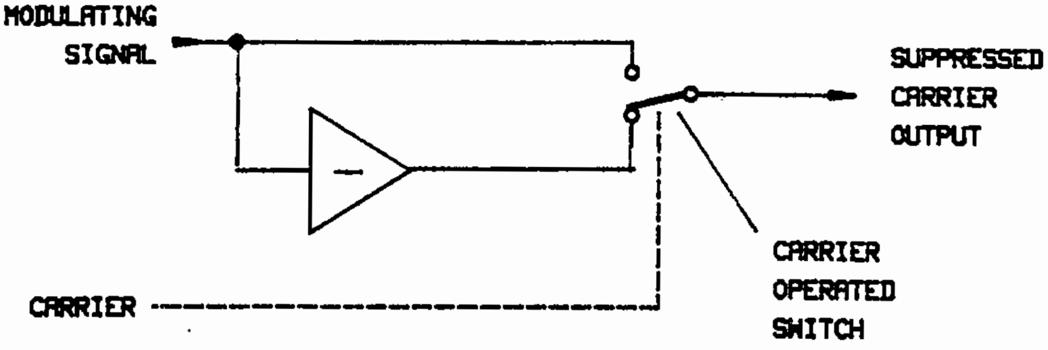


Figure 2-9. Principal of Operation of a Suppressed Carrier Modulator.

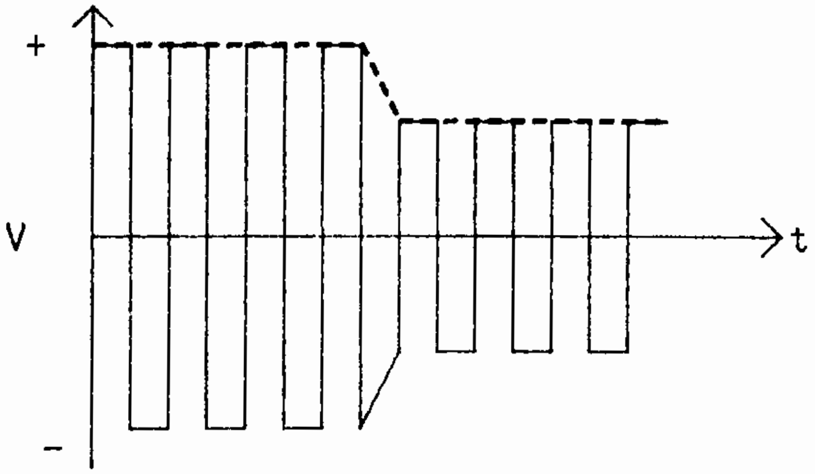


Figure 2-10. Waveform of a Switching type Modulator.

This type of modulator will perform the two characteristics established in Section 2-4, but, for a steady D.C. modulating signal input, the output will be a square wave. Passing the output of the switch through a low pass filter will remove the harmonic components (in practice, mainly the second and third harmonics) to restore the waveform to a sine wave. The modified block schematic is shown in figure 2-11, together with its associated waveforms in figure 2-12.

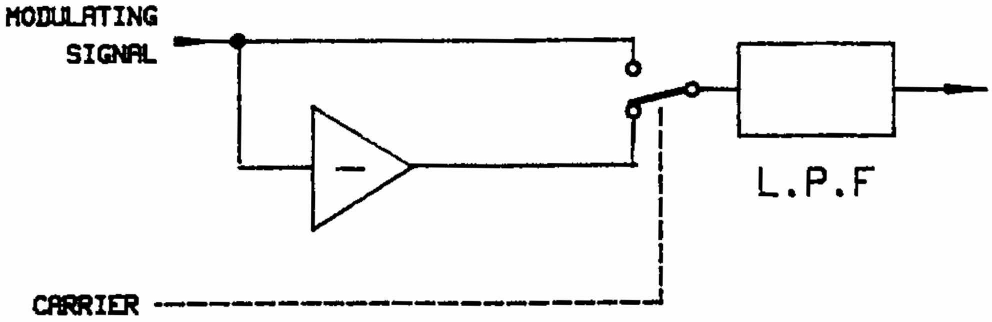


Figure 2-11. Suppressed Carrier Modulator with a Filter.

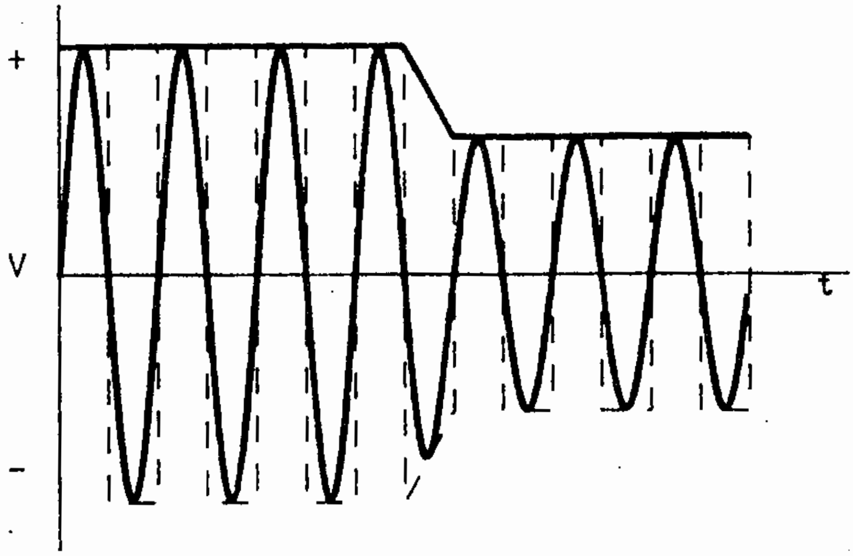


Figure 2-12. Output Waveform of Suppressed Carrier Modulator with Filter.

2.6 A PRACTICAL SUPPRESSED CARRIER MODULATOR

A practical suppressed carrier modulator may be constructed using four transistors as a two pole two-way switch, and is shown simplified without bias circuitry in figure 2-13.

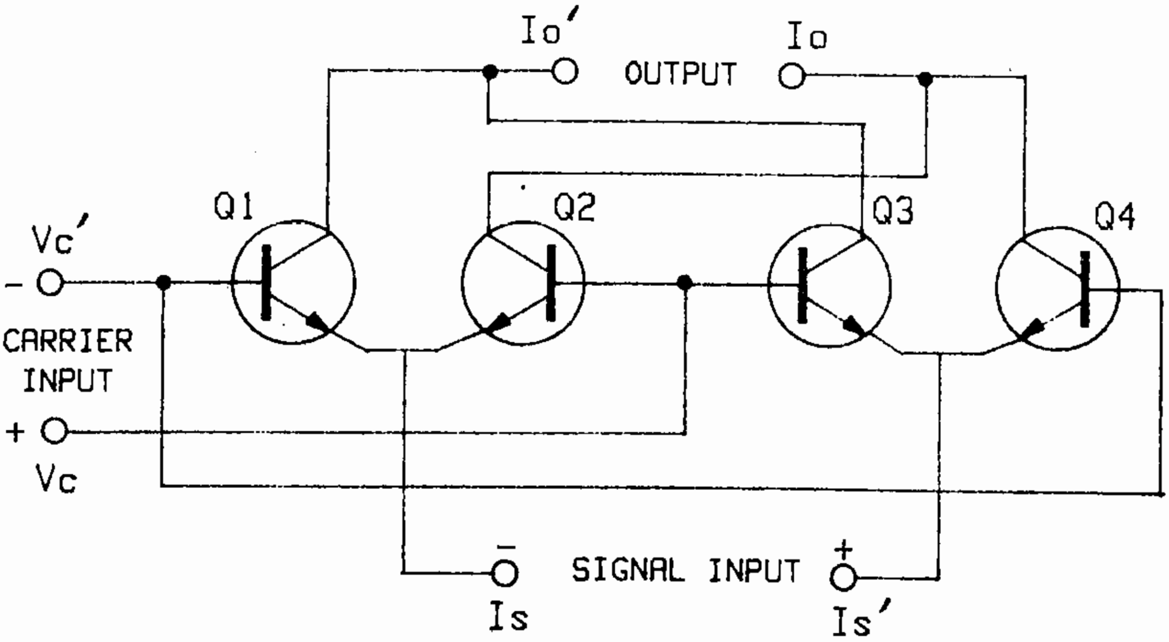


Figure 2-13. A Simplified Suppressed Carrier Modulator Circuit.

The carrier is used as a switching signal in this configuration. During the carrier half cycle when Vc is positive with respect to Vc' , transistors Q2 and Q3 are switched hard on and transistors Q4 and Q1 are cut off. This will pass the modulating signal input current from Is to Io, Is' being switched to Io'. During the negative going half cycle of the carrier, transistors Q4 and Q1 are switched on and transistors Q2 and Q3 are driven into cut off. This will now transfer the input current from Is to Io' and Is' will be switched to Io.

This configuration is using four transistors to switch currents. In practice, however, an output voltage will generally be required, whose amplitude and phase is dependent on the modulating signal input voltage and polarity. The input voltage can be converted into a current using a constant current generator, and the output current can be converted into a voltage using a collector load resistor.

By adding these extra components, the circuit now becomes as shown in figure 2-14.

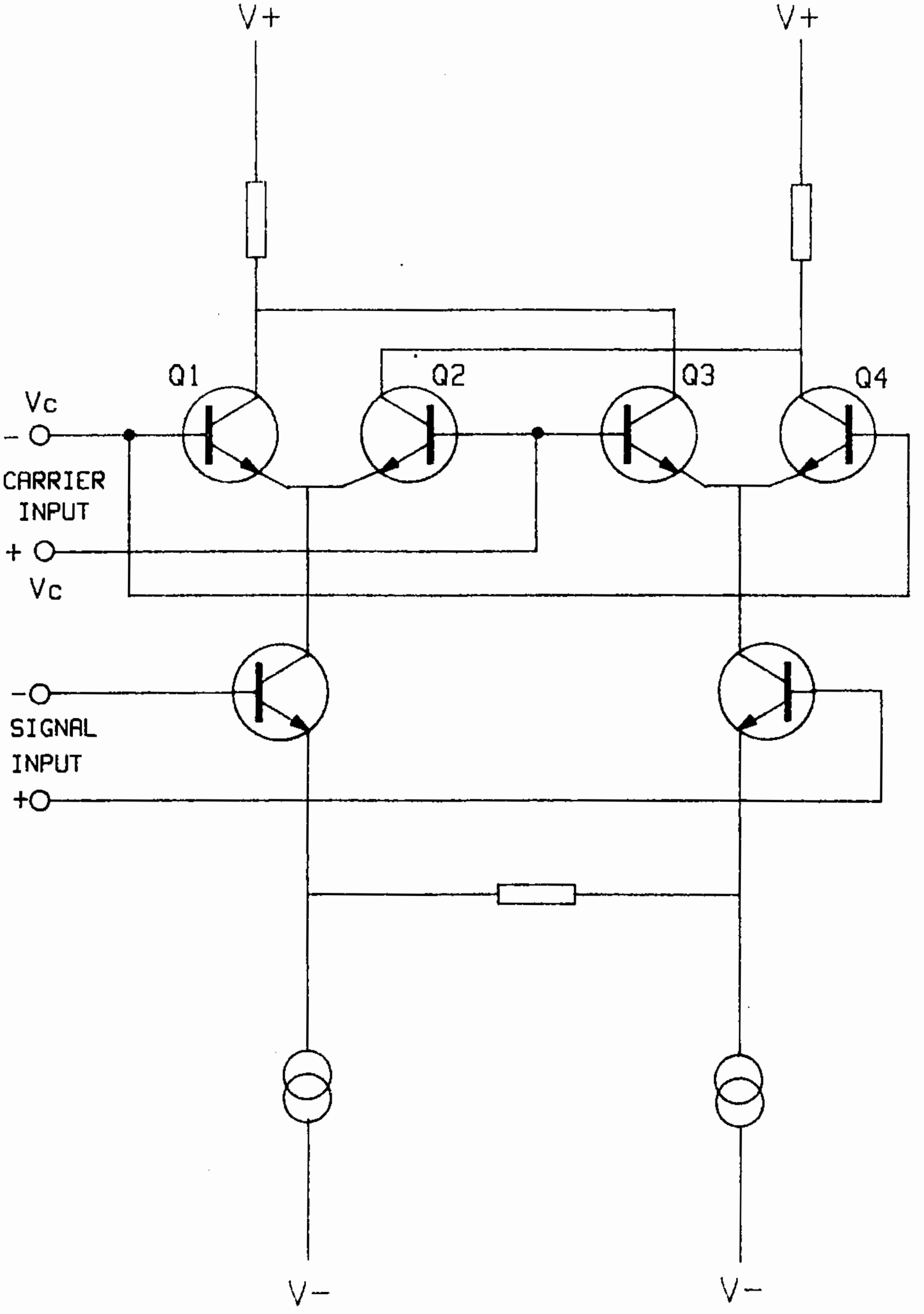


Figure 2.14. A Theoretical Circuit for a Suppressed Carrier Modulator.

In practice, the two constant current sources will be transistors connected in a common emitter configuration with a fixed bias fed to their basis. The final practical circuit then becomes as shown in figure 2-15.

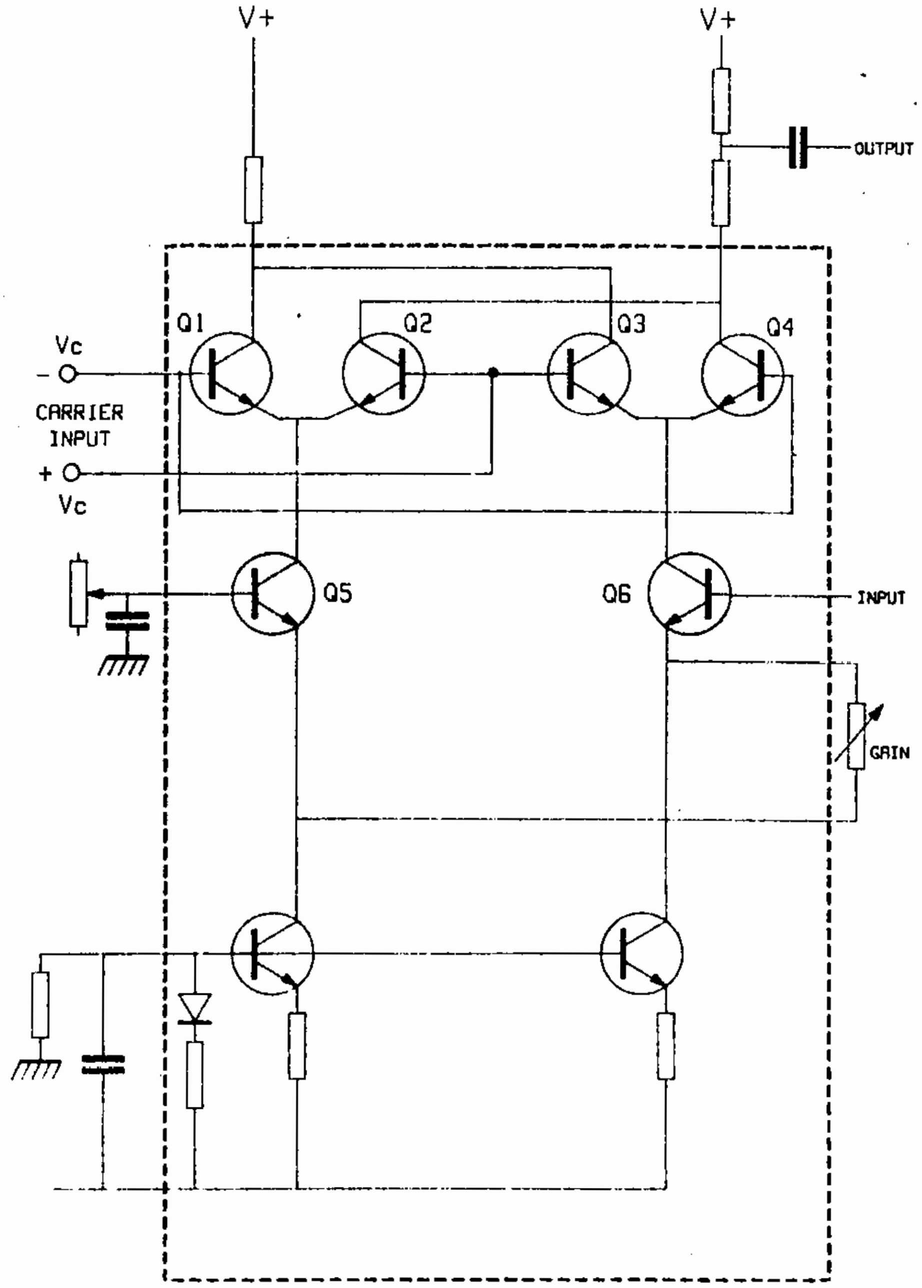


Figure 2.15. A Practical Suppressed Carrier Modulator Circuit.

A variable resistor connected between the emitters of Q5 and Q6 may be used to adjust the overall gain of the modulator.

In modern practice, the circuit contained within the heavy broken line will be contained on a single integrated circuit. An MC1596 is a typical example of this, although the 1495, 1496 and 1595 are other variations.

2.7 DEMODULATION.

Demodulation is the reverse process to modulation. Modulation was achieved by alternately switching the modulating signal between its normal and inverted value. The switching in the modulator was achieved by using the carrier. If the same carrier was then used to switch the inverted parts of the modulating signal back again, the original modulating signal would then be reconstituted. If it is assumed that no subsequent filtering took place, the process could then be shown as shown in figure 2-16.

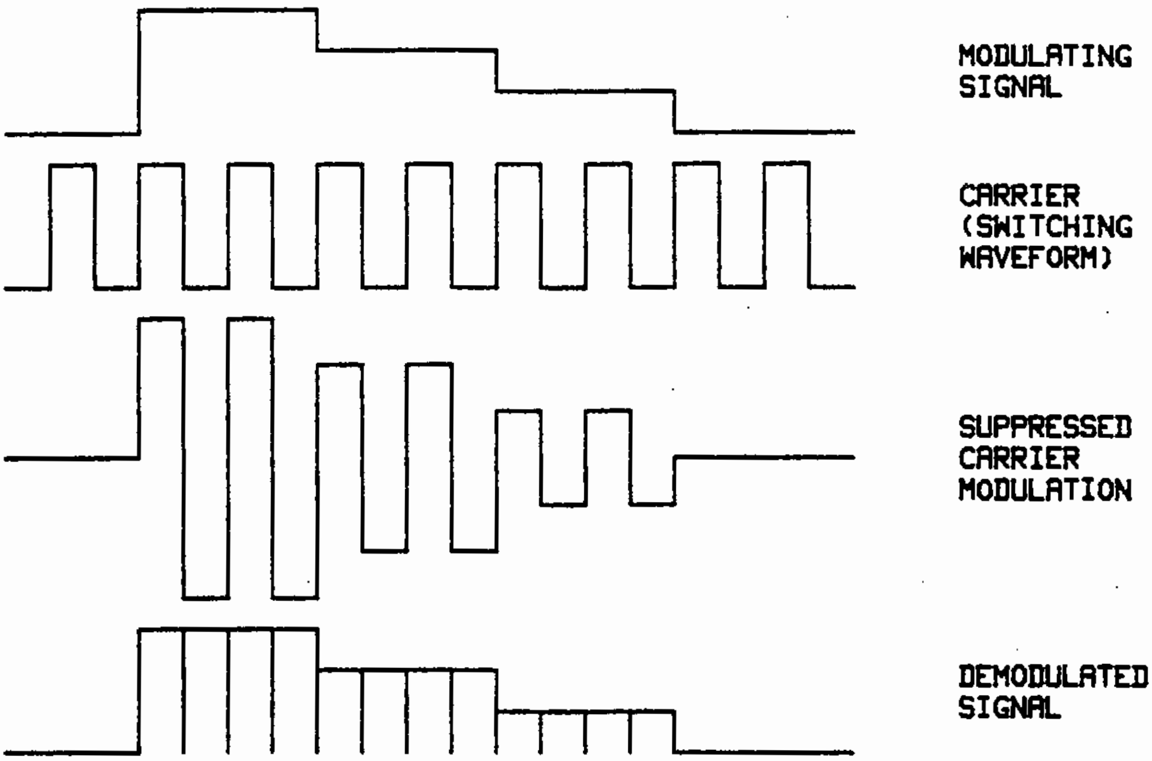


Figure 2-16. Suppressed Carrier Modulation and Demodulation.

In practice, the modulated signal would have been filtered to remove the harmonics,so the process would be as shown in figure 2-17. It can been seen from this that the subsequent output waveform again must be filtered to remove the carrier component.

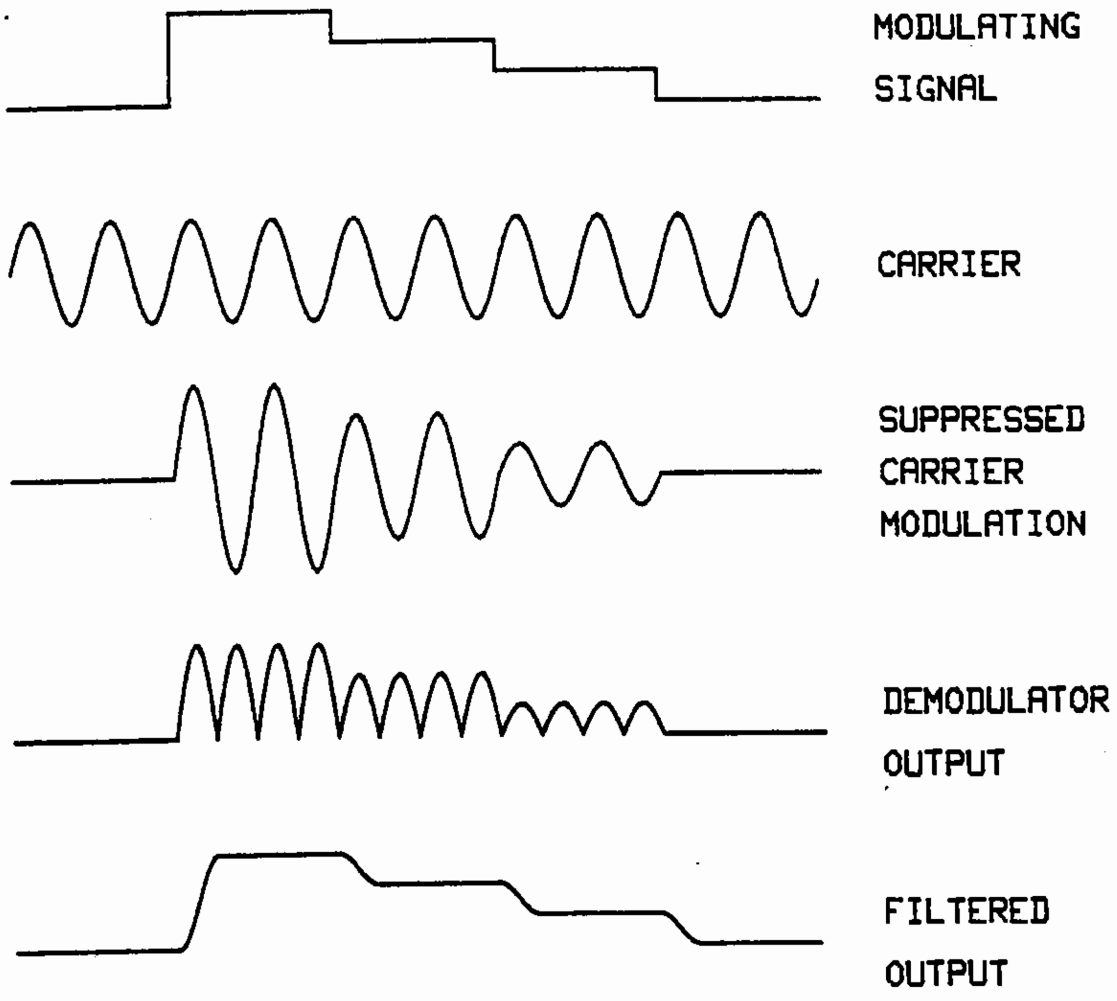


Figure 2.17. Practical Modulator and Demodulator Waveforms.

This example has only assumed positive values of modulating signal. Colour difference signals, however, may be negative.

CPQ7

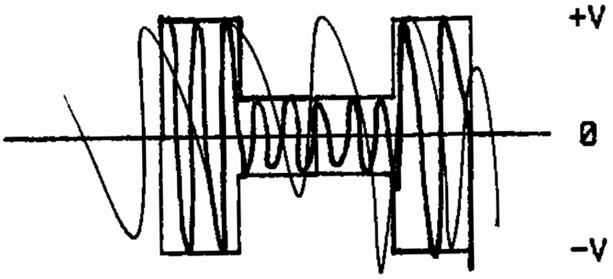
For the modulating signal shown below, draw the waveforms that you would expect:-

(a) At the output of the modulator (after filtering),

(b) At the output of the demodulator (before filtering);

(c) At the output of the demodulator (after filtering);

(d) At the output of the demodulator, both before and after filtering, if the phase of demodulating subcarrier is shifted by 180°.



You can now check your answer to CPQ7 by following the instructions to be found in the practical **LFC3.**

After completing this investigation, have your result checked by a supervisor before continuing with the text.

You can now see that the actual operation of a demodulator is almost the same as a modulator. In practice, the MC1596 multiplier integrated circuit may be used either as a modulator or demodulator. The symbolic representation of a modulator, as shown in figure 1-1, may also be used for a demodulator.

2.8 TWO CHANNEL QUADRATURE MODULATION.

The proceeding sections have established that, provided the reference demodulating subcarrier is in the correct phase, the correct output will be obtained from the demodulator. If, however, the demodulating subcarrier is inverted (or phase shifted by 180°), the inverse of the original modulating signal is obtained at the demodulator output. In the practical investigation LFC2, you saw how varying the phase of the reference demodulating subcarrier through 180° reduced the amplitude of the output to zero and then increased its amplitude until it reached its correct value but inverted. The fact that no output was seen if the reference demodulating carrier was 90° out of phase, can be used to send two information channels using one carrier frequency. Two carriers are used at the same frequency but with a 90° phase relationship, this is known as QUADRATURE MODULATION.

If two suppressed carrier modulators are fed with reference carriers in quadrature, they will both produce outputs at the same frequency, but again in quadrature to each other. If these two resulting modulated signals are then added together, since they are both of the same frequency, the resultant signal will also be a sine wave of this frequency, but of some intermediate phase dependent on their relative amplitudes. This is illustrated in figure 2-18.

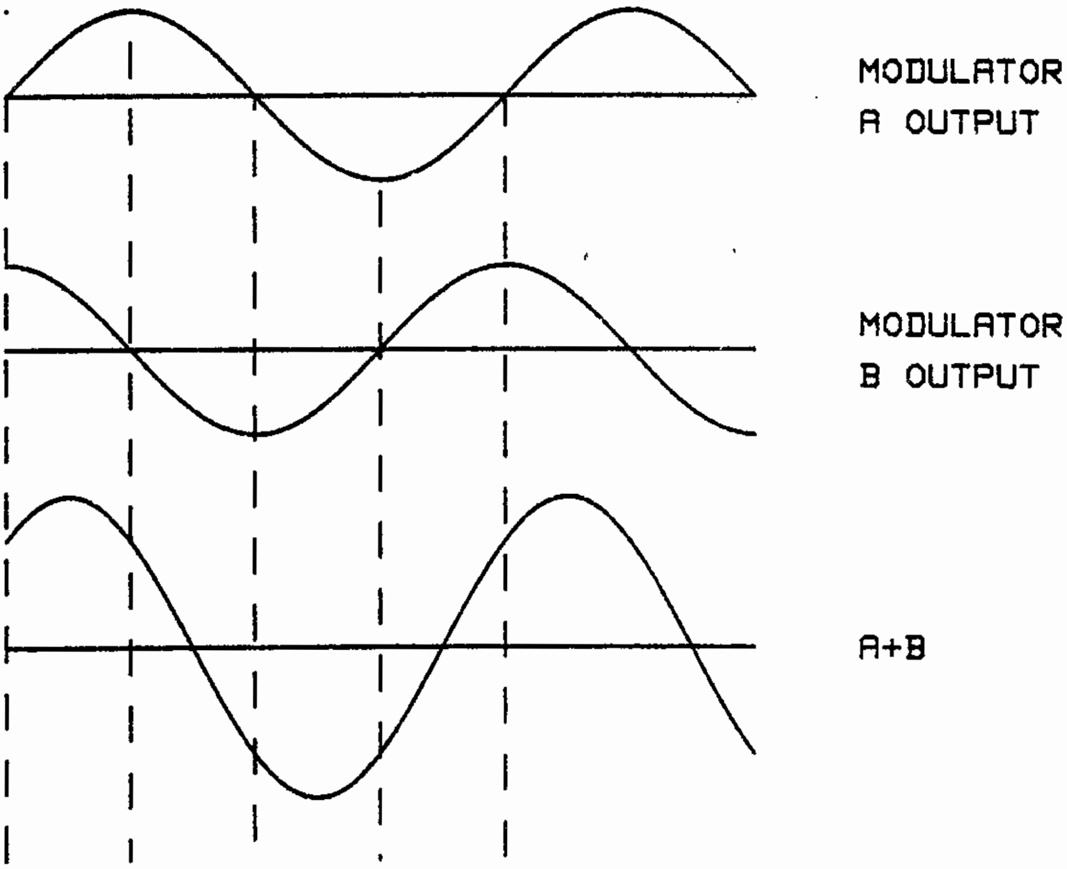


Figure 2-18. Addition of Two Sine Waves in Quadrature.

Demodulation of this quadrature modulated signal can easily be achieved by using two demodulators fed with reference carriers in quadrature. It is, however, very important that the phase difference between the two modulating carriers is exactly 90°. This also applies to the two demodulating carriers. The phase of the reference carrier fed to a demodulator must be exactly 90° to the carrier of the other unwanted signal, if perfect separation is to be achieved.

The three main characteristics of suppressed carrier modulation can now be listed as follows:-

(a) The amplitude of the envelope is directly proportional to the amplitude of the modulating signal.

(b) The phase of the modulated signal is dependent on the polarity of the modulating input.

(c) Two signals may be transmitted together by adding the outputs of two modulators fed by reference carriers in quadrature.

2.9 CHROMINANCE TRANSMISSION WITH SUPPRESSED CARRIER MODULATION

The three basic characteristics of suppressed carrier modulation make it an ideal method to transmit the two colour difference signals, both of which could have either positive or negative values.

A simplified schematic of the chrominance signal path is shown in figure 2-19.

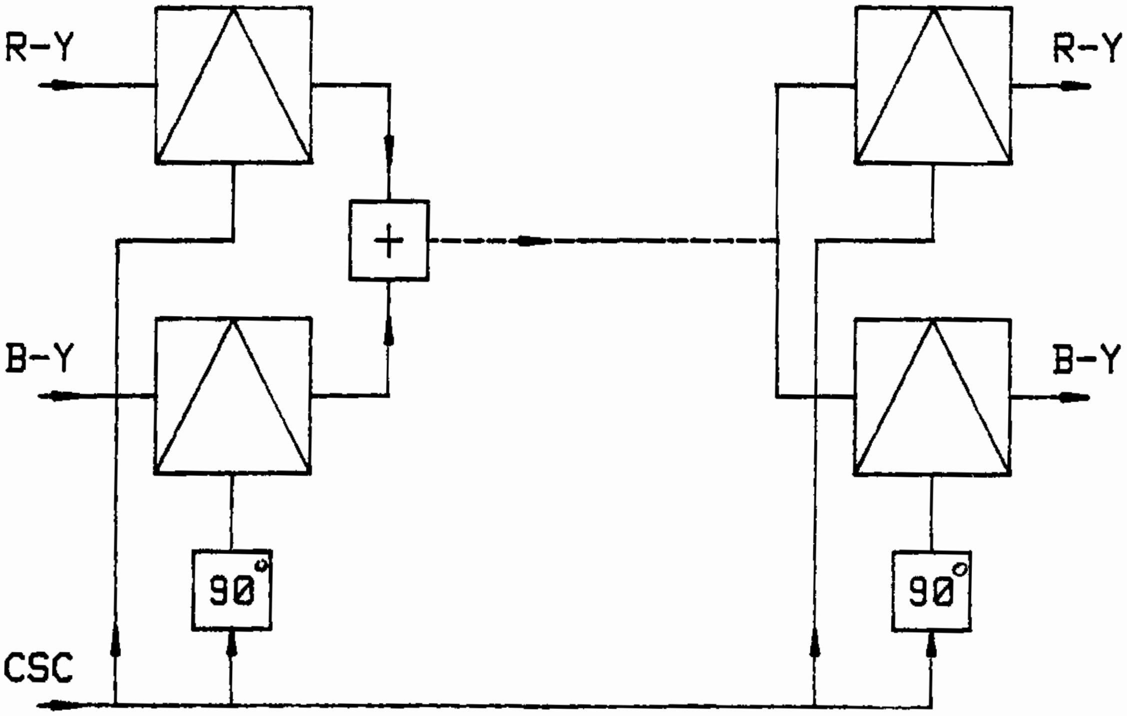


Figure 2-19. Basic Chrominance Signal Transmission.

2.10 REQUIREMENT OF THE COLOUR BURST

It has been shown that it is very important to ensure that the phases of the demodulating carriers are exactly the same as those used by the modulators. In figure 2-19, this is achieved by supplying them both from the same feed of colour subcarrier. This implies a separate transmission path for the reference signal, with exactly the same amplitude and phase characteristics as the chrominance path. This is not possible in practice.

A practical solution to this is to use an oscillator in the decoder as the reference. This oscillator must be locked accurately in frequency and phase to the modulators' reference carrier. To achieve this, a sample of the modulators' reference carrier is sent on the same transmission path as the chrominance signal. As they both cannot be sent at the same time, the sample, known as the COLOUR BURST, is sent during the back porch of line blanking each line, except for nine lines during the field sync interval. This colour burst takes the form of about ten cycles of reference subcarrier.

The negative (B - Y) axis is chosen for the reference burst.

Figure 2-20 shows the finalised chrominance signal transmission path using a separate demodulating phase locked oscillator, which is usually referred to as a B.L.O. (Burst Locked Oscillator)

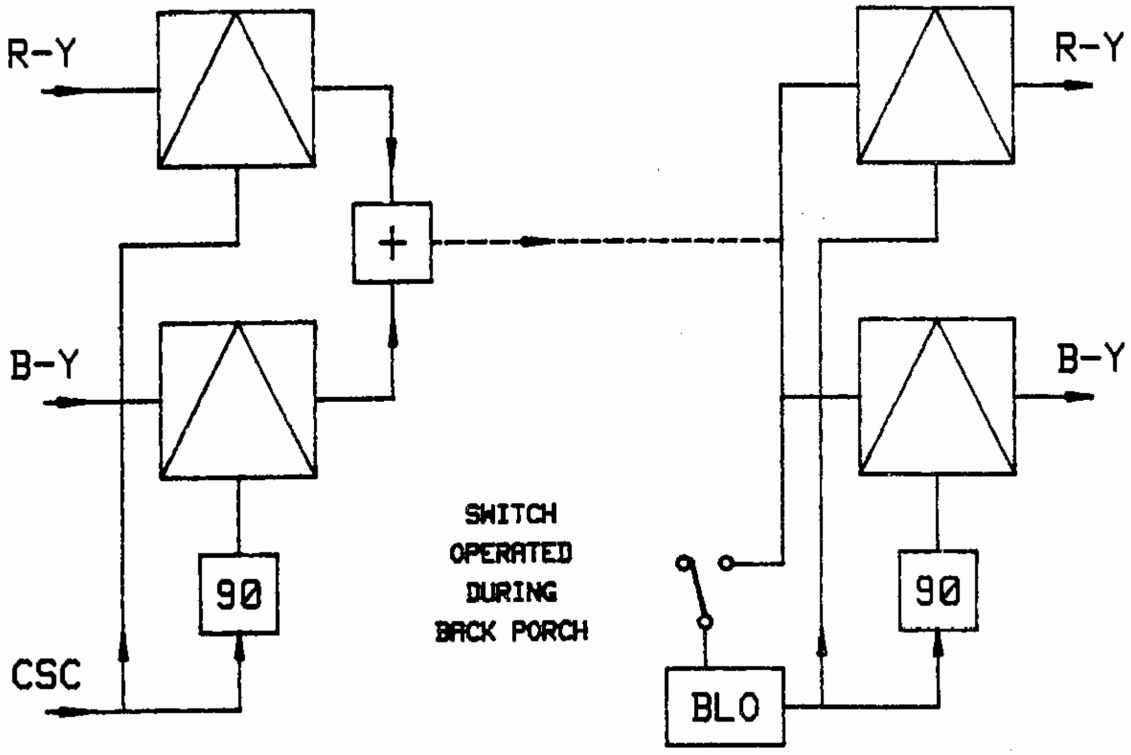


Figure 2-20. Chrominance Signal Transmission Path.

The characteristics of quadrature modulation are best noted by examining the waveforms produced when certain parameters are changed. Turn to the practical unit and undertake the remaining investigations with the low frequency coder, numbers **LFC4**, **LFC5** and **LFC6.**

SECTION 3

VECTOR REPRESENTATION OF SUPPRESSED CARRIER MODULATION

SECTION 3 VECTOR REPRESENTATION OF SUPPRESSED CARRIER MODULATION

3.1 Vector representation
3.2 Vector scales
    Fig. 3-1 Vector representation of modulator outputs
    Fig. 3-2 Vector representation of chrominance signals
    Fig. 3-3 Table of chrominance vector amplitudes and phases
    Fig. 3-4 Summary of chrominance vectors
3.3 Information contained in vector representation.

CFQ8

3. VECTOR REPRESENTATION OF SUPPRESSED CARRIER MODULATION

3.1 VECTOR REPRESENTATION

Whatever colour difference signals are produced by a picture source, when coded they will result in a chrominance signal which is sinusoidal.

The variations of the two colour difference signal amplitudes are transferred to variations of the subcarrier amplitude and phase in the coder. The combined amplitude and phase of a sine wave may be represented vectorially, and this method is frequently used.

3.2 VECTOR SCALES

The chrominance signals corresponding to (R - Y) and (B - Y) are in quadrature, i.e. they differ in phase by 90°. If the value of either colour difference signal is negative, this will result in an inversion of its corresponding subcarrier, i.e. 180° phase shift.

Considering the separate outputs of the two modulators, there are four possible phases, i.e. positive (R - Y), negative (R - Y), positive (B - Y) and negative (B - Y). These four phases, mutually at 90°, may be represented vectorially as shown in figure 3-1.

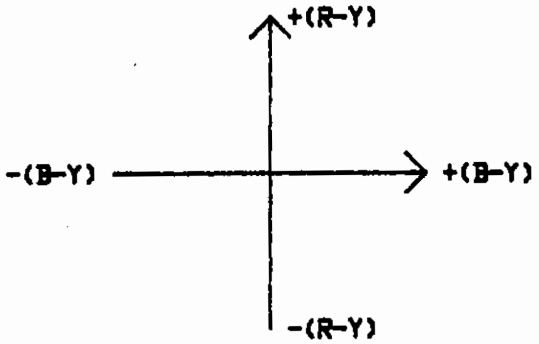


Figure 3-1. Vector Representation of the Modulator Outputs.

In your answer to CPQ5, the amplitudes and polarities of both the colour difference signals were established for the fully saturated primary and complementary colours. The relative amplitudes and phases of their corresponding chrominance signals may now be represented on this vector diagram, as shown in figure 3-2.

[At this stage, it is useful to consider the chorominance vectors in 'J notation'. The (B - Y) components will lie on the real axis and the (R - Y) components on the imaginary or 'J' axis. The resultant vector obtained by combining the output of the two modulators is the point plotted at C = (B - Y) + j(R - Y).]

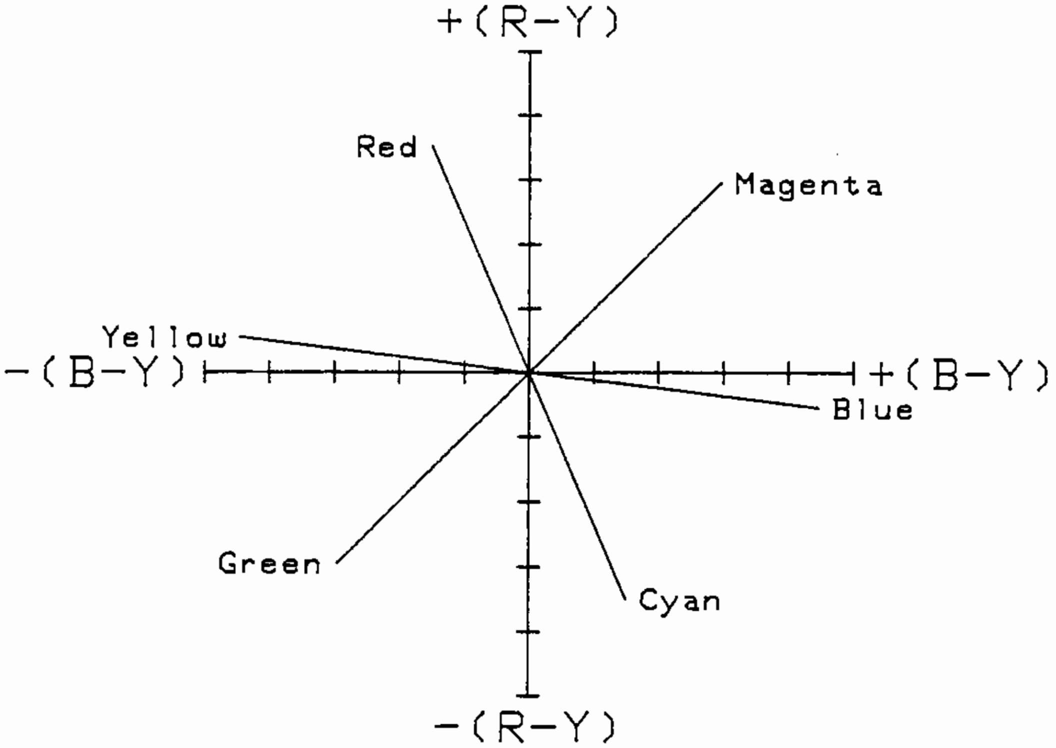


Figure 3-2. Vector Representation of the Chrominance Vectors.

If the chrominance vectors were represented in polar form [i.e. $C\,\underline{/\theta}$ where $C = \sqrt{} (R - Y)^2 + (B - Y)^2$ and $\theta = \tan^{1} (R - Y) \div (B - Y)$] the amplitudes and phases of each vector can be calculated. These figures are tabulated in figure 3-3.

Colour	R	G	B	Y	R-Y	B-Y	Chrom	Angle
White	1	1	1	1	0	0	0	-
Yellow	1	1	0	.89	+.11	-.89	.9	173°
Cyan	0	1	1	.70	-.7	+.3	.76	293°
Green	0	1	0	.59	-.59	-.59	.83	225°
Magenta	1	0	1	.41	+.59	+.59	.83	45°
Red	1	0	0	.30	+.7	-.3	.76	113°
Blue	0	0	1	.11	-.11	+.89	.9	352°
Black	0	0	0	0	0	0	0	-

Figure 3.3. Chrominance Vector Amplitudes and Phase Angles.

The table in figure 3.3 enables the relative amplitude and phases of the chrominance vectors to be assessed. The main features found from your vector diagram and the table above may be tabulated as shown in figure 3.4.

HUE	POLARITY OF COL. DIFF. SIGS		MODULATOR OUTPUT PHASES		RESULTANT CHROMINANCE PHASE
	R-Y	B-Y	R-Y	B-Y	
MAGENTA	+	+	90	0	1st QUADRANT
RED & YELLOW	+	−	90	180	2nd QUADRANT
GREEN	−	−	270	180	3rd QUADRANT
CYAN & BLUE	−	+	270	0	4th QUADRANT

Figure 3-4. Summary of Chrominance Vectors.

3.3 INFORMATION CONTAINED IN VECTOR REPRESENTATION.

From the table in figure 3-3 which was summarised in figure 3-04, it can be seen that the PHASE angle of the combined chrominance vector represents the HUE of the colour transmitted.

The AMPLITUDE of the chrominance vector represents the degree of SATURATION of the colour.

CPQ8

Before continuing with Section 4, plot a vector diagram on graph paper for the following RED colours of different amplitudes and saturations. This will be easier for you to do if you first establish a table of the relevant values of R, G, B and Y, together with their consequent values of (R - Y) and (B - Y).

a) 100% amplitude, 100% saturation
b) 50% amplitude, 100% saturation
c) 100% amplitude, 50% saturation
d) 50% amplitude, 50% saturation.

Your vector diagram produced in CPQ8 should confirm that the chrominance vectors for all these pure red colours have the same phase angle. Note the effect of reducing the amplitude of a 100% saturated colour.

The AMPLITUDE of the chrominance vector is thus not only dependent on the SATURATION of a colour, but also on its BRIGHTNESS.

Note that achromatic pictures (eg. black, grey and white) have zero colour difference and chrominance signals.

The effect of adding the chrominance signal to the luminance signal can now be examined.

SECTION 4

THE COMPOSITE CODED VIDEO SIGNAL

SECTION 4. THE COMPOSITE CODED VIDEO SIGNAL

4.1 Derivation of the coded video and signal
    Fig. 4-1 Composite coded video waveforms
    CPQ 9
    CPQ 10
4.2 Principles of weighting
    Fig. 4-2 Table of weighted chrominance values
    CPQ 11
4.3 Standard nomenclature of colour bars
    Fig. 4-3 100/0/100/0 (100%) Colour Bar waveforms
4.4 Main features of 100% Colour Bars
4.5 Other colour bar signals
4.6 95% Colour Bars
    Fig. 4-4 100/0/100/25 (95%) Colour Bar waveforms
4.7 E.B.U. Colour Bars
    Fig. 4-5 100/0/75/0 (E.B.U.) Colour Bar waveforms
4.8 NTSC Coding and Decoding
    CPQ 12
    Fig. 4-6 Interconnection of an NTSC Coder and Decoder
4.9 An NTSC Coder
4.10 An NTSC Decoder
    Fig. 4-7 Block Diagram of an NTSC Coder and Decoder.

4. THE COMPOSITE CODED VIDEO SIGNAL.

4.1 DERIVATION OF THE CODED VIDEO SIGNAL

In section 3.2 the amplitudes of the luminance and chrominance signals for each step on the colour bar waveform were established. The composite coded video is simply an addition of these two signals. The effect of combining these signals is shown in figure 4-1.

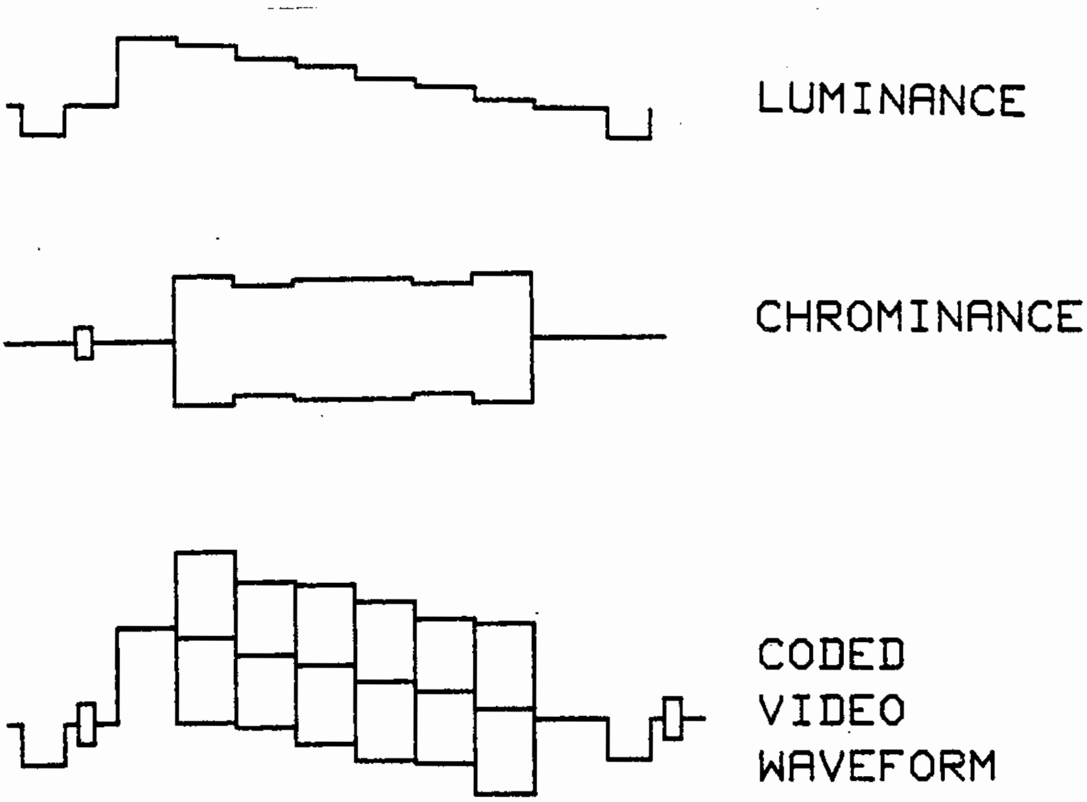


Figure 4-1. Composite Coded Video Signal Waveforms.

CPQ9.

With reference to the various signal amplitudes contained in the coded video waveform shown in figure 4-1, write down the main features you notice and state any reasons why you think this waveform is not suitable for transmission.

If the composite coded video signal established so far was transmitted, it would be distorted by the overall system performance. When the chrominance signal is added on to the luminance signal, the overall amplitude is increased. If no action was taken, the transmitter would be over-modulated and the extreme excursions of the chrominance signal would be lost. The modulating signal gain at the input to the transmitter could be reduced to avoid this. This, however, would result in a lower picture or video signal amplitude when detected in the viewer's receiver.

CPQ10.

If the composite coded video signal were transmitted at such a level as to avoid over modulation, what would be the effect of this on the viewer's receiver?

4.1 PRINCIPALS OF WEIGHTING.

Earlier in this module, the need for compatability and reverse compatability was discussed. These requirements mean that the luminance signal component of our coded video signal cannot be changed. This implies that the chrominance signal must be modified.

Any reduction in chrominance signal amplitude will result in a reduced chrominance signal to noise ratio. By careful analysis of the chrominance components, it can be shown that most of the extreme excursions of the chrominance signal are due to the (B - Y) component. Some reduction of then (R - Y) component is, however, still required. If the amplitude of the (B - Y) signal is reduced by just over a half and the (R - Y) signal by about one eighth, then the best compromise is reached to receive the optimum signal to noise ratio whilst maintaining system compatability. The (B - Y) and (R - Y) colour difference signals after weighting are known as the U and V signals. Hence,

$$U = 0.493\ (B - Y)$$

and $$V = 0.877\ (R - Y).$$

Using these factors, a final table of luminance and chrominance amplitudes can be produced. This is shown in figure 4-02.

Colour	R	G	B	Y	U	V	Chrom	Angle
White	1	1	1	1	0	0	0	-
Yellow	1	1	0	.89	-.44	+.10	.45	167°
Cyan	0	1	1	.70	+.15	-.61	.63	284°
Green	0	1	0	.59	-.29	-.52	.59	241°
Magenta	1	0	1	.41	+.29	+.52	.59	60°
Red	1	0	0	.30	-.15	+.61	.63	104°
Blue	0	0	1	.11	+.44	-.10	.45	35°
Black	0	0	0	0	0	0	0	-

Figure 4-2. Table of Luminance and Chrominance Values for 100% Bars.

(Note - The phase angle (θ) of the chrominance vector is measured relative to the + (B - Y) axis).

Using the values shown in this table, the NTSC colour bar waveform can now be established.

CPQ11.

On a piece of graph paper, draw an NTSC composite coded colour bar waveform. Use the values shown in the table in figure 4-2. Remember these values are in signal units where one signal unit equals 0.7 volts. A line sync pulse (0.3V) is equivalent to 0.43 signal units (as shown on page 3 of the notes, 1 x (0.3/0.7). The reference burst amplitude is 0.3 volts peak to peak and occurs from approximately t = +5.6 μseconds, to t = 7.85 ~~+11.8~~ μseconds relative to the line sync leading edge. Since at this stage the amplitudes of the signal are of major concern, a scale of 5 centimetres for one signal unit for the amplitude and a scale of 1 centimetre for each colour on the time scale will be convenient.

Before continuing, ask your supervisor to check your waveform.

The colour bar waveform that you have drawn is that for 100% amplitude, 100% saturated colour bars. This waveform is known as 100% bars. The colours are 100% amplitude because the R, G and B values are always either 0.7 volts (one signal unit) or 0 volts. In stating that they are 100% saturated, it is implied that for each hue there is only one or two primary colours present, and they are present to their full extent. There are other types of colour bars, but they are not encountered very often in the broadcast chain.

4.3 STANDARD NOMENCLATURE OF COLOUR BARS.

A colour bar waveform has four basic amplitude parameters and these may be derived from their R, G and B component values. The perameters may be expressed as four percentage numbers, e.g. 100/0/100/0, defined as follows:-

First Number - The percentage value of the R, G and B signals present in the white bar.

Second Number - The percentage value of the R, G and B signals present in the black bar.

Third Number - The maximum percentage value of the R, G and B signals for the coloured bars.

Fourth Number The minimum percentage value of the R, G and B signals for the coloured bars.

The three component signals for 100/0/100/0 colour bars (known as 100% bars) are shown, together with the composite coding signal in figure 4-3.

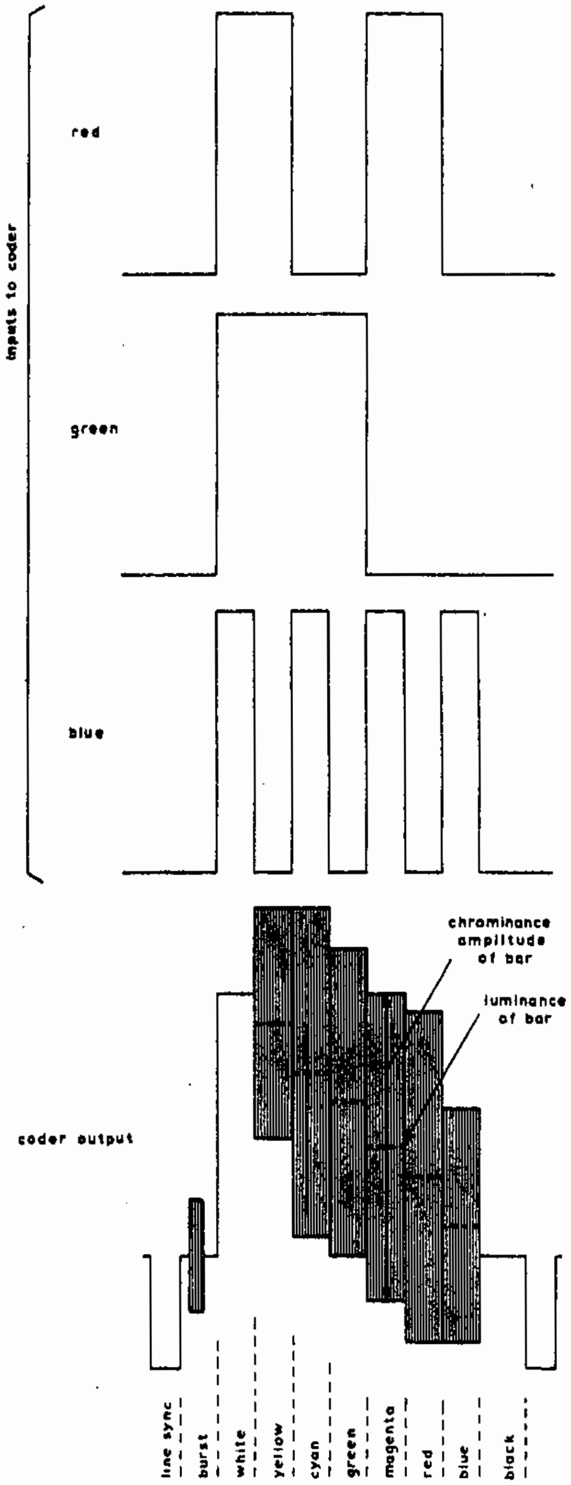


Figure 4-3. 100/0/100/0 (100% Bars) Colour Bar Waveforms.

4.4 MAIN FEATURES OF 100% BARS.

The main features of 100% colour bars at the standard level are:-

(a) Luminance level for the white bar is 0.7V

(b) Luminance level for the black bar is 0.0V (Blanking level)

(c) Positive chrominance peaks for yellow and cyan are at the same level (because of the weighting factors chosen for the U and V signals)

(d) By symmetry of the waveform, the negative peaks of the red and blue bars are at the same level.

(e) The positive peaks of the magenta chrominance signal are at white level.

(f) The negative peaks of the green chrominance signal are within 3mV of black level.

NOTE:-

This last feature of the 100% bars waveform can usefully be used as a check for correct chrominance amplitude relative to the luminance amplitude.

This colour bar waveform is very useful as a colour line up. It is difficult, however, to identify the change between the end of the black bar and the start of the front porch of line blanking. To alleviate this problem, most colour bar generators have the durations of each coloured bar slightly reduced to allow sufficient time for a further white bar at the end of the line.

4.5 OTHER COLOUR BAR SIGNALS

100% bars are only used internally and are never transmitted. With reference to the 100% Bars waveform in Figure 4-3, it can be seen that the negative peaks of the chrominance signal for magenta., red and blue extend below blanking level. Whilst for an average picture, which generally does not contain highly saturated colours, this is no problem, the fully saturated colours for the 100% Bars signal could cause mis-triggering on line timebases of early colour receivers. To overcome this 95% bars are transmitted. 100% Bars are also a very stringent test and are not representative of colours normally encountered in practice.

4.6 95% Bars.

95% Colour Bars still have an amplitude of 100% (for white and the colours), but all the colours are de-saturated with 25% of white. The standard nomenclature for 95% Bars is thus 100/0/100/25.

Whilst 95% bars are electrically 75% saturated. they appear 95% saturated in practice due to the non-linearity of the C.R.T.

The characteristics of 95% bars can be seen from the waveform in Figure 4-4, and may be summarised as,

(a) Luminance level for white bar is 0.7 volt,

(b) Luminance level for black bar is 0.0 volt,

(c) Positive chrominance peaks for yellow and cyan are at the same level (above white level),

(d) Negative chrominance peaks for the red and blue bars are equal, and are equal to black level.

(e) Positive chrominance peaks of magenta are at white level, but

(f) Negative chrominance peaks of green lie above black level.

4.7 E.B.U. Bars.

The European Broadcasting Union have adopted another standard of colour bars as an international line-up signal. The value of the R, G and B signals are adjusted to ensure that chrominance positive peaks do not extend above white level.

The standard nomenclature for E.B.U. bars is 100/0/75/0. Since the maximum amplitude of the R, G & B signals for the six coloured bars is only 75% of white level, E.B.U. bars are sometimes referred to as 75% bars.

The characteristics of E.B.U. bars can be seen from Figure 4-5 and may be summarised as:-

(a) Luminance level for white bar is 0.7 volt.

(b) Luminance level for black bar is 0.0 volt.

(c) Positive chrominance peaks for the yellow and cyan bars are equal and the same as white level.

(d) Negative chrominance peaks for the red and blue bars are equal but lie below black level.

(e) Positive peaks of the magenta chrominance lie below white level.

(f) Negative peaks of the green chrominance signal occur at black level.

4.8 NTSC CODING AND DECODING

All the main features of an NTSC colour transmission system for 625 lines have now been considered. The principles which have been examined in detail so far can now be included in a block diagram for an NTSC coder and decoder. Initially these two units can be shown connected as in figure 4-6. Both the coder and decoder will have certain input and output signal requirements.

CPQ12

On the NTSC system block diagram, figure 4-6, label the input and outputs of the coder and decoder. On a separate sheet, list the main functions the inputs to the coder will have to perform and summarise the methods used to produce the output signals from the decoder.

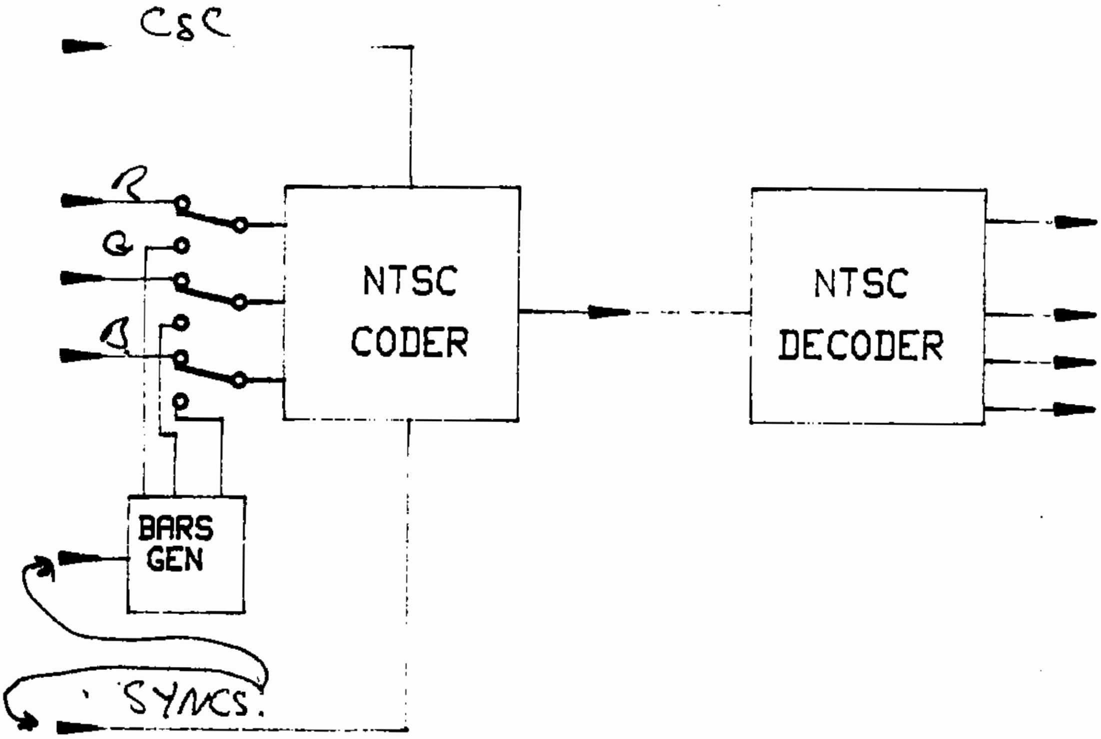


Figure 4-6: Interconnection of an NTSC Coder and Decoder

NOTE In earlier systems the colour bar generator was a separate unit, but modern coders have an integral bars generator with the facility for input switching.

The main features of the NTSC colour television system have now been examined and these can now all be included in block diagram form for a coded transmission path.

4.9 NTSC CODER

The signal source produces R, G & B outputs which are fed to a CODER. The main features to be included in an NTSC coder are as follows:-

a) production of a luminance (or Y) signal such that
$Y = 0.3R + 0.59G + 0.11B$.

b) production of weighted colour difference signals by using a usually passive matrix such that
$U = 0.493(B - Y)$ and
$V = 0.877(R - Y)$.
n.b. $U = 0.493\ [B - (0.3R + 0.59G + 0.11B)]$
$= 0.493\ (0.89B - 0.3R - 0.59G)$
and $V = 0.877\ (0.7R - 0.59G - 0.11B)$

c) bandlimiting of U signal.

d) bandlimiting of V signal.

e) the V signal modulates the colour subcarrier.

f) a short period of negative going voltage is added to the U signal to generate the colour burst in the -U phase during the back porch.

g) a 90° phase shift is applied to the reference sub carrier fed to the U modulator.

h) the U signal modulates the 90° phase shifted sub carrier.

i) the outputs of the two modulators must be added to produce the chrominance signal.

j) the harmonics must be filtered from the chrominance signal

k) addition of mixed syncs to the luminance signal.

l) the composite luminance signal must be delayed to match the delays introduced by the chrominance filters and modulators.

m) the chrominance signal must then be added to the composite luminance signal to produce the composite coded output. On some modern equipment this is often labelled C.V.B.S. (Chrominance, Video, Burst and Syncs).

4.10 NTSC DECODER

The input to the decoder is a composite coded video signal and the features to be included in the decoder are as follows.

The NTSC decoder:-

a) separates mixed sync pulses from the video signal.

b) separates the luminance signal from the coded video input using a band stop filter to remove the chrominance.

c) separates the chrominance information from the coded input using a band pass filter.

d) uses a switching signal derived from the mixed syncs to isolate the colour burst.

e) uses the ten cycles of reference sub carrier on the -U axis to phase lock a Burst Locked Oscillator (B.L.O.). This regenerated reference is arranged to lie on the V axis.

f) uses the output of the B.L.O. to demodulate the V chrominance component to obtain the (R - Y) signal.

g) phase shifts the B.L.O. reference by 90° to feed the U demodulator

h) demodulates the chrominance in the U axis using the 90° phase shifted reference subcarrier to obtain the (B - Y) signal

i) filters residual subcarrier components from the demodulated colour difference signals

j) provides a (G - Y) signal from matrixing the (R - Y) and (B - Y) signals such that

$$(G - Y) = -\frac{0.3}{0.59}(R - Y) + \frac{0.11}{0.59}(B - Y)$$

$$= -(0.508\,(R - Y) + 0.186\,(B - Y)$$

k) delays the separated luminance signal to compensate for the delay in the chrominance filters (i)

l) adds the luminance signal to the three colour difference signals (R - Y), (B -Y) & (G - Y) to produce R, G & B outputs.

All these features of an NTSC coder and decoder may be connected in block diagram form as shown in Figure 4-7.

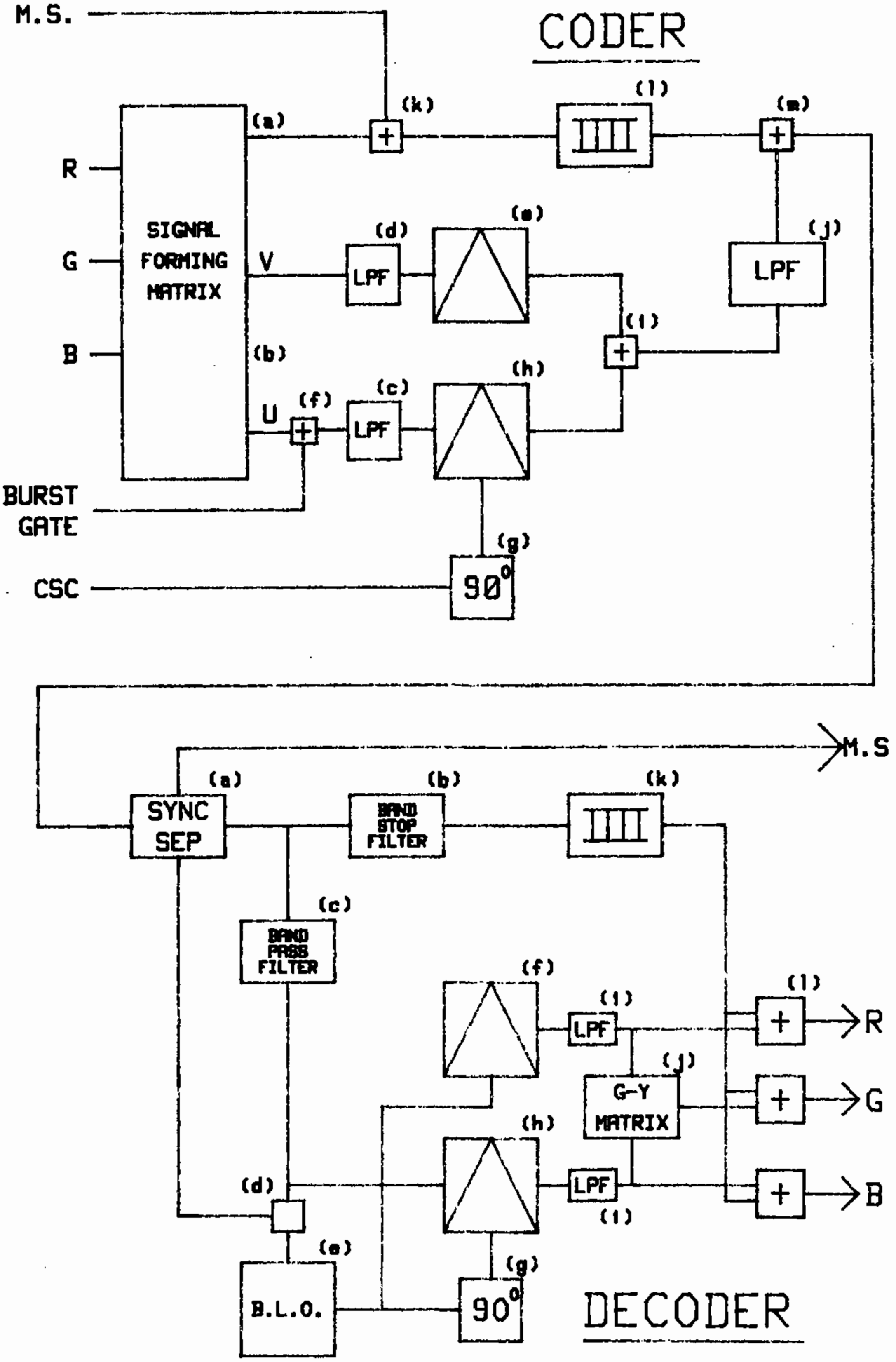


Figure 4-7. Block Diagram of an NTSC Coder & Decoder.

SECTION 5

DISTORTIONS

SECTION 5. DISTORTIONS

5.1 Types of distortion

5.2 Differential gain distortion

Fig. 5-1 A coded video signal (a) without distortion
(b) with differential gain distortion

5.3 Differential phase distortion

Fig. 5-2 Demodulated waveform (a) without distortion
(b) with differential phase distortion

CFQ 13

PRACTICALS **COD 1** to **COD 7.**

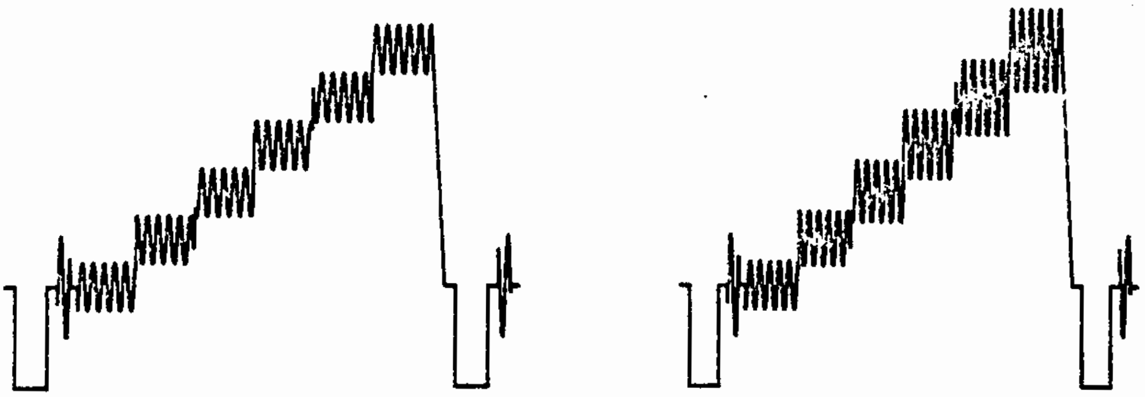
5. DISTORTIONS

5.1 TYPES OF DISTORTION

It has been shown in Section 4 that the amplitude of the chrominance signal determines the saturation of the signal and that the phase of the chrominance signal determines the hue. It was also shown in the previous package that, owing to the non-linearity of the picture C.R.T., the colour difference signals effectively convey luminance information. It is possible that a change in amplitude and/or phase of the subcarrier (relative to the burst) may take place during the transmission of the coded signal. This will result in poor colorimetry of the reproduced picture. These two types of distortion can be considered separately.

5.2 DIFFERENTIAL GAIN DISTORTION

Consider a luminance signal rising in 5 steps from black level to white level. If a constant amplitude of subcarrier is added to this as shown in Figure 5-1(a), its amplitude should stay constant over the transmission path. If the amplitude of the subcarrier varies (it could be an increase or a decrease) and this amplitude variation is dependant on the luminance level, then this effect is known as differential gain distortion. An example of this is shown in figure 5-1(b).



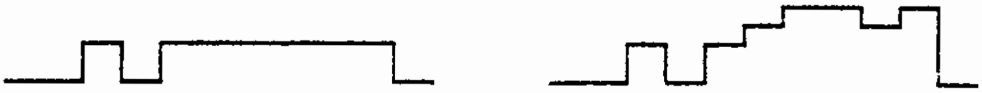
(a) (b)

Figure 5-1. A Coded Video Signal (a) Without and (b) With Differential Gain Distortion.

Differential gain distortion only results in saturation and brightness errors.

5.3 DIFFERENTIAL PHASE DISTORTION

Consider the same luminance signal but with an added subcarrier of constant phase. When this chrominance is demodulated, the demodulator output should be a steady d.c. If, however, the phase of the subcarrier varies and this phase change is directly as a result of the luminance level it is superimposed on, then this distortion is known as differential phase. The result obtained when an signal with and without differential phase is demodulated is shown in Figure 5-2.



(a) (b)

Figure 5-2. Waveform produced after demodulating a signal (a) without and (b) with differential phase distortion.

DIFFERENTIAL PHASE distortion produces predominantly HUE ERRORS.

NOTE. Whilst differential gain and differential phase are examined separately, they are usually found together.

There is another source of phase distortion which may be present in a colour system. This occurs when the colour burst or demodulator reference carrier does not lie on the correct axis. This can happen if the burst is removed and then re-inserted at a later stage (e.g. in a video-tape recorder or vision mixer), or if the B.L.O. in the demodulator does not lock exactly 90° lagging the burst. The latter effect frequently happens in domestic television receivers.

CPQ13.

If the B.L.O. in an NTSC decoder locked up a few degrees out of phase, what effect would you expect this to produce,

(a) on the colour difference signals, and

(b) on the displayed picture?

The effect of phase distortion is best seen on a monitor. If you now turn to the practical unit and after reading the introduction to the coder demonstration unit undertake the investigations **COD 1** to **COD 7**, you will be able to see a simulated colour television system in operation.

SECTION 6

BROADCAST COLOUR SYSTEMS

SECTION 6. BROADCAST COLOUR SYSTEMS

6.1 The NTSC System
6.2 The SECAM System
    Fig. 6-1 A simplified SECAM coder block diagram
    Fig. 6-2 Use of a delay line in a SECAM decoder
6.3 The PAL System.

6. BROADCAST COLOUR SYSTEMS.

6.1. THE NTSC SYSTEM.

Sections 4 and 5 have explained the principles of an NTSC system.

Any phase distortion (differential phase or overall phase) will vary the phase of the chrominance subcarrier during some part or all of the active picture relative to the colour burst. Since the subcarrier phase dictates the received hue, this will produce hue errors.

The NTSC system does have the advantage that the coded signal may easily be processed during the broadcast video chain, e.g. the coded signal may be faded to black without altering the luminance to chrominance amplitude relationship.

6.2. THE SECAM SYSTEM.

The SECAM system only transmits one colour difference signal at a time. During one line the subcarrier is FREQUENCY MODULATED by one colour difference signal, and during the next line the other colour difference signal is fed to the modulator. The use of frequency modulation makes the system able to withstand considerable amounts of amplitude and phase distortion, but the effects of multipath reception however may be noticable.

Unlike NTSC and PAL, the two carriers which are modulated by the two colour difference signals have different frequencies (282 x line frequency and 272 x line frequency) for zero modulation (neutral scenes). The deviations of the two modulators are also different. To enable the decoder to detect the line sequence, 9 lines of synchronisation signals are sent during field blanking.

A typical simplified SECAM coder is shown in Figure 6.1.

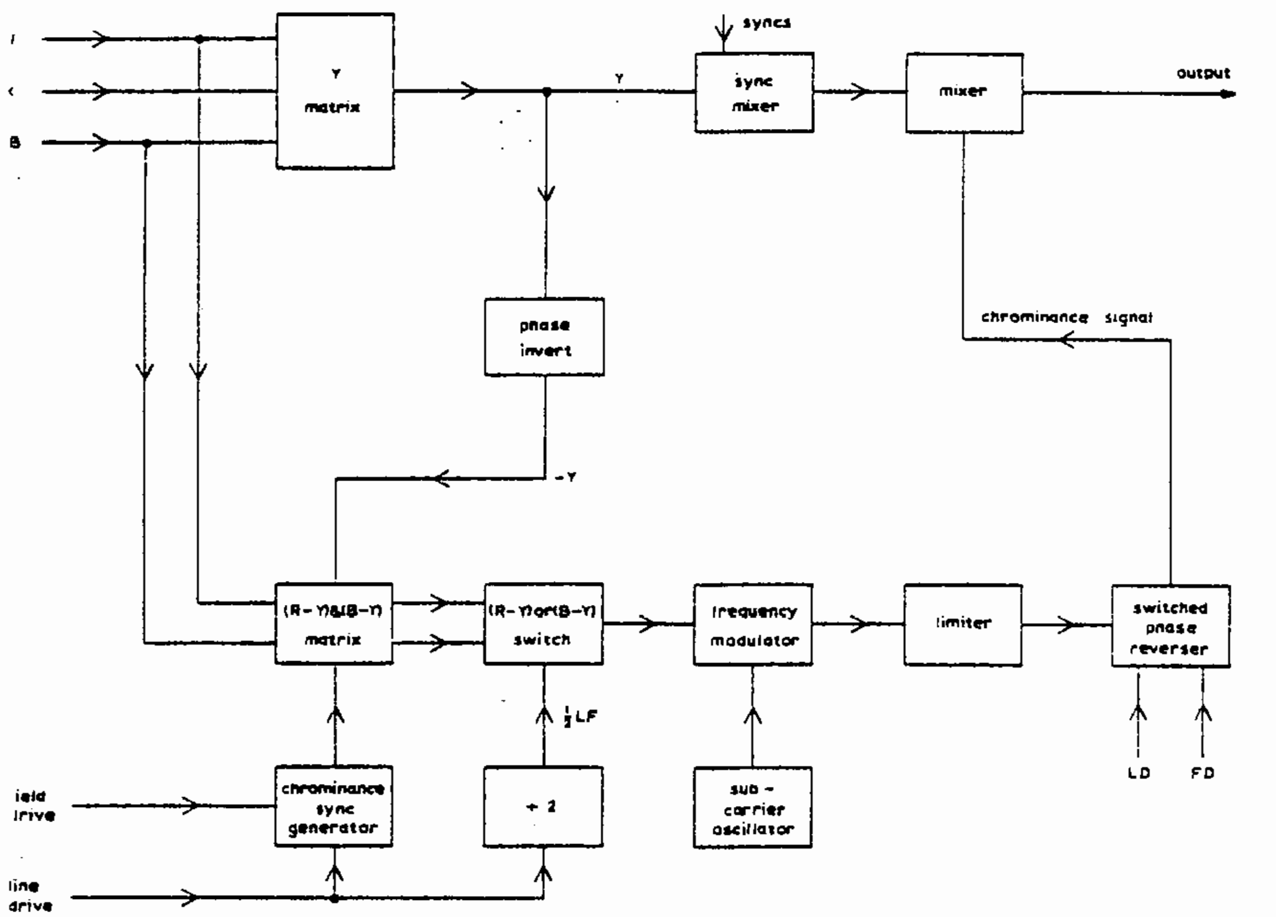


Figure 6-1. A Simplified SECAM Coder Block Diagram.

In the decoder a delay of one line duration is provided to make both modulated colour difference signals available at any time for demodulation. Figure 6-2 shows how this is achieved.

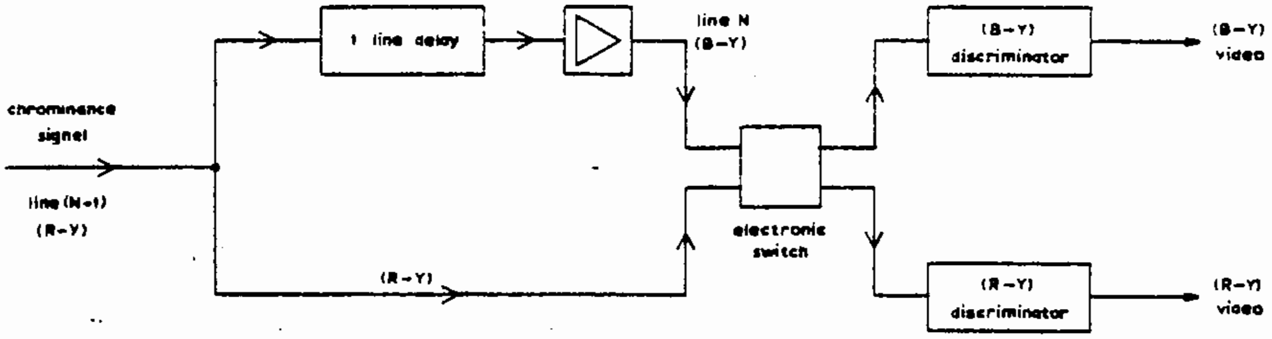


Figure 6-2. Use of delay line in a SECAM decoder.

If a coded SECAM signal were to be faded to black, as may be required in a mixer, the luminance signal would be reduced in amplitude, but the same amplitude of colour difference signals would still be present after demodulation (giving over saturated pictures) until insufficient chrominance signal was available resulting in a monochrome picture. A SECAM vision mixer must demodulate the signals prior to fading (or mixing) in order to overcome this problem.

6.3. THE PAL SYSTEM.

The PAL system uses a modification to the NTSC system designed to overcome the effect of phase distortions.

The V modulator output has a 180° phase inversion applied on alternate lines. (Phase Alternating Line).

This has the effect on alternate lines of altering the direction of any hue change produced. The errors can then be averaged either by the eye or electronically. How this is achieved and the effect that phase distortions produce will be examined in Section 7.

SECTION 7

THE PAL SYSTEM

SECTION 7. The PAL SYSTEM.

7.1 Principle of the PAL system
    Fig. 7-1 Magenta vector (a) without distortion
    (b) with 12° of phase error
    CPQ 14
7.2 Modifications required for a PAL coder
    CPQ 15
    CPQ 16
    CPQ 17
    Fig. 7-2 The PAL Colour Burst
7.3 PAL Coder Block Diagram
    Fig. 7-3 The PAL Coder Block Diagram
    Fig. 7-4 Theoretical 100% Colour Bar Waveforms
7.4 Modifications required for a PAL decoder
    CPQ 18
    Fig. 7-5 Regeneration of CSC and VAS in a PAL decoder
7.5 The PAL 4 field sequence
7.6 Phase Distortion with PAL
    Fig. 7-6 Affect of phase distortion on the magenta vector
    CPQ 19
    PRACTICAL **COD 8**
7.7 Hanover Bars
7.8 The Delay Line PAL Decoder principle
    Fig. 7-7 Operation of a Delay Line Decoder
7.9 Operation of a Delay Line Decoder
7.10 Hue errors with PAL-D
    Fig. 7-8 Affect of phase distortion on a magenta vector
    (a) on line n, and
    (b) on line n + 1
    CPQ 20
7.11 Saturation errors with PAL-D
    Fig. 7-9 Vector addition in a PAL-D decoder
7.12 The PAL decoder block diagram
    Fig. 7-10 A PAL decoder block diagram
    PRACTICALS **COD 9** to **COD 10**
7.13 Phase distortion in PAL-D decoders.

7. THE PAL SYSTEM

7.1 PRINCIPLE OF THE PAL SYSTEM

The last practical observations you made demonstrated how objectionable phase errors appear. Any modification to the system that can be adopted to reduce the effect of these will be beneficial. The phase errors you saw were overall phase errors, i.e. the decoder B.L.O. was not locked in the correct phase.

Consider a magenta signal that undergoes a phase shift distortion. The vector representation of this is shown in Figure 7-1.

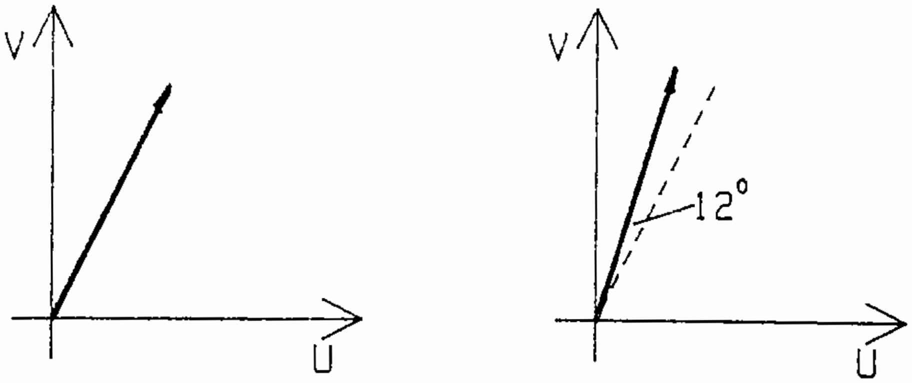


Figure 7-1. Magenta vector (a) ideally (b) with 12° of phase error.

The effect of a positive phase error is to make the magenta appear too red.

What effect would the same error have on a Cyan colour?

CPQ14.

Draw a vector diagram for 100% saturated cyan and show the effect of a positive phase error of 12% on this signal. What effect would this have on the reproduced colour.

Your answer to CPQ14 should show that the cyan colour is reproduced too blue. This effect could be likened to that of a negative phase error on magenta which would have made it appear too blue.

This means that a fixed phase error in one direction will produce a different effect on the viewed colour depending on the original phase of the chrominance signal. The PAL system utilises this fact to apply a degree of automatic correction for phase errors.

An overall phase error, caused by a B.L.O. locking to the burst with a phase error, or the mean phase of the burst being incorrect, will cause the decoding axes to rotate. This has the same effect as all the vectors being rotated by the same fixed angle.

Differential phase distortion will rotate the affected vectors individually with respect to the axes. The amount of rotation will depend upon the amount of this distortion, which will in turn depend on their individual luminance levels.

7.2 MODIFICATIONS REQUIRED FOR THE PAL CODER

Taking magenta as an example, the PAL system transfers the magenta vector from the 1st quadrant to the 4th quadrant on alternate lines. It achieves this by reversing the polarity (i.e. applying a 180° phase shift) of the V chrominance signal. The magenta signal originally had values of $U = 0.29$ and $V = 0.52$, so its vector could be represented in j notation as $M = 0.29 + j\,0.52$. On alternate lines, the coder converts this to $M = 0.29 - j\,0.52$ so that it lies in the 4th quadrant.

CPQ15.

Given that the polar representation of a magenta vector is $M = 0.59\ \underline{/60^\circ}$, what will be the polar representation for the magenta chrominance vector on the alternate lines?

The switching of the V signal polarity is achieved in a PAL coder by a 0/180° switch. The switching is initiated by a V Axis Switch waveform (V.A.S.). This waveform may either be supplied from the same sync pulse generator as the mixed sync signal, or in later coders derived from the incoming mixed sync and burst gate waveforms. The VAS waveform is a half line frequency square wave timed coincident with the leading edge of the line sync component of mixed syncs.

An overall phase error, caused by a B.L.O. locking to the burst with a phase error or the mean phase of the burst being incorrect, will cause the decoding axes to rotate. This has the same effect as all the vectors being rotated by the same fixed angle.

Differential phase distortion will rotate the affected vectors individually with respect to the axes. The amount of rotation will depend on their individual luminance levels.

CPQ16.

If the output of a PAL Coder were fed into an NTSC decoder, what colour would magenta be reproduced as? What modification do you think is required to an NTSC decoder to convert it into a PAL decoder?

Before considering a PAL decoder, a further modification to the coder must be considered. The PAL decoder requires information to enable it to detect which type of line it is decoding, i.e. does it have to switch the V axis or not. This information can be contained within the colour burst.

The burst used in the NTSC system is transmitted in the -U phase. The burst in the PAL system on one line has a phase mid-way between the +V and -U axes, on the next line it has a phase midway between the -V and -U. It is produced in the coder by adding a positive pulse to the V signal for the duration of the colour burst, in addition to the negative pulse added to the U signal.

CFQ17.

i) If the vector representation of the unswitched colour burst in the PAL system is CB = $- {}^{0\ 15}/_{\sqrt{2}} + j\ {}^{0\ 15}/_{\sqrt{2}}$ volts what are the polar values of the colour burst vector.

(a) on a normal line, and

(b) on a line with the V axis switched by 180°.

Draw these two values on a vector diagram, together with the two vectors produced by magenta, given that U = 0.41 volts and V = 0.72 volts.

ii) What is the peak-peak value of the colour burst?

Ask your supervisor to check your answer and then copy the 4 vectors onto the diagram below.

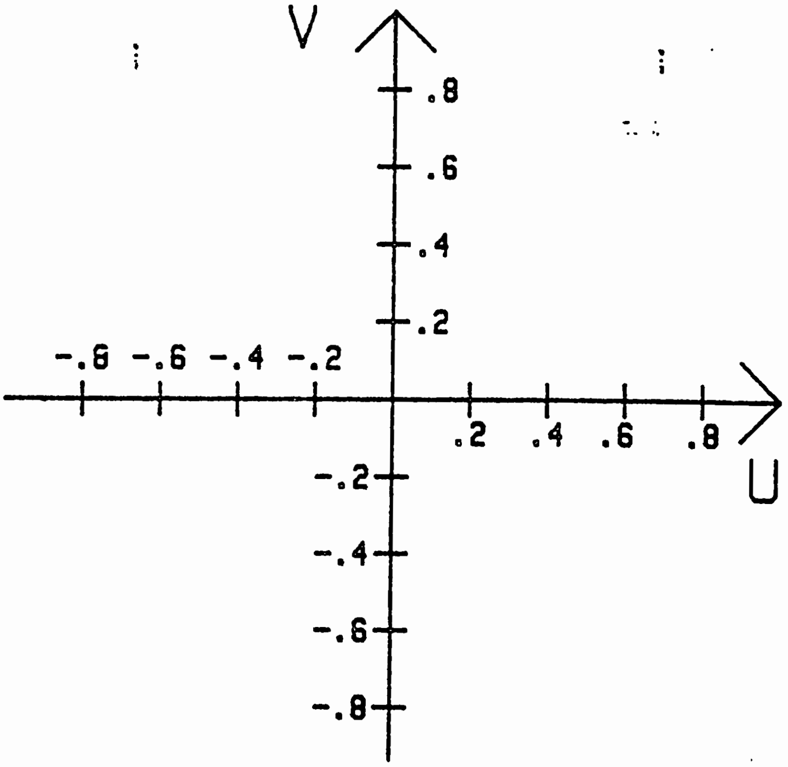


Figure 7-2. The PAL Colour Burst

7.3 PAL CODER BLOCK DIAGRAM

The extra features required in a PAL coder can now be added to the block diagram of Figure 4-7. The modifications required for the PAL system coders are:-

(a) addition of the 0/180° PAL switch fed with the VAS waveform.

(b) modification to the U and V signals to generate the burst at 135° relative to the U axis.

A typical block diagram of a PAL coder is shown in Figure 7-3; and Figure 7-4 shows the waveforms that would be found throughout the coder.

[(G -Y) is included for reference, although this waveform would only be found in the decoder.]

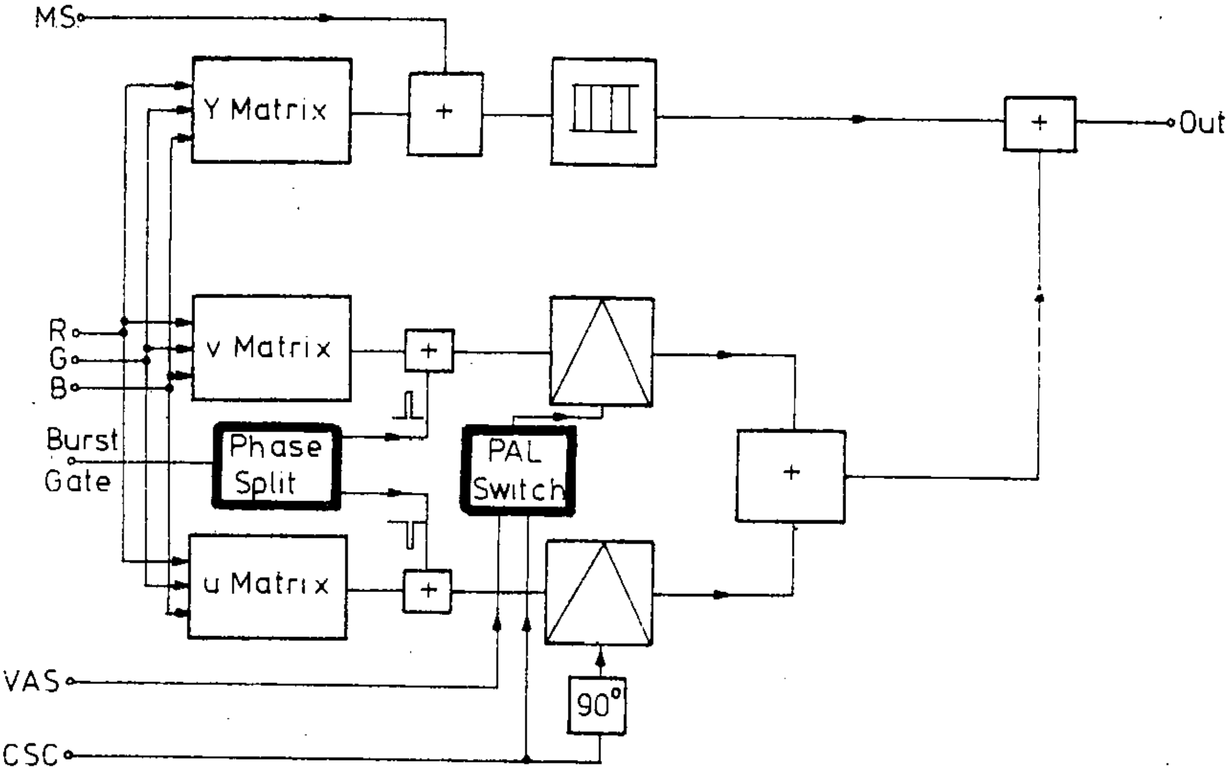


Figure 7-3: PAL Coder Block Diagram

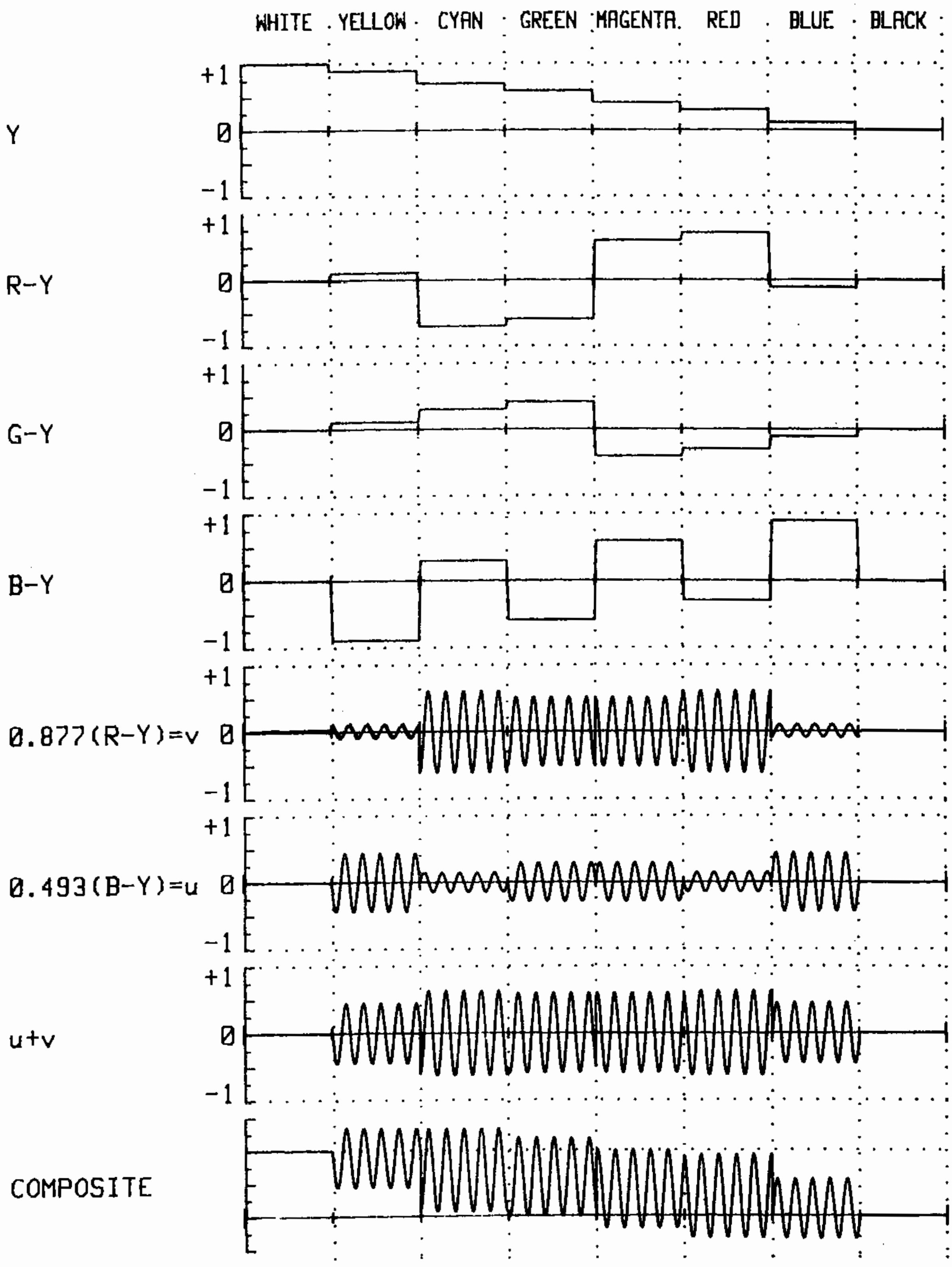


Figure 7-4: Theoretical Waveforms For a Set of Colour Bars

7.4 MODIFICATIONS REQUIRED FOR A PAL DECODER

Your answer to CPQ15 should have identified the requirement of a PAL decoder to restore the switched V axis to normal. To enable it to do this, it ulitises the VAS information contained within the colour burst.

CPQ18.

In a decoder, the phase of the B.L.O. is compared with that of the burst on each line and an error signal used to lock the phase of the oscillator to that of the incoming burst.. What sort of error signal would you expect from a colour burst in the PAL system?

The decoder B.L.O. must lock to the mean phase of the burst. The error signals produced by the comparator must be averaged over a number of lines. This is achieved by feeding the error signals into a long time constant C.R. circuit (viz: integrating circuit). Having locked the B.L.O. to the mean phase of the burst, comparison can now take place on a line by line basis, i.e. a short time constant circuit. This will produce a positive and a negative error on alternate lines. The specification of the VAS waveform is that it is timed coincident with the leading edge of line sync pulses. This can be achieved in the PAL decoder by using the error signal produced by comparing the phase of the burst with its mean phase. This is used to steer a bistable multivibrator clocked by line sync leading edges

A block diagram for this part of a PAL decoder is shown in Figure 7-5.

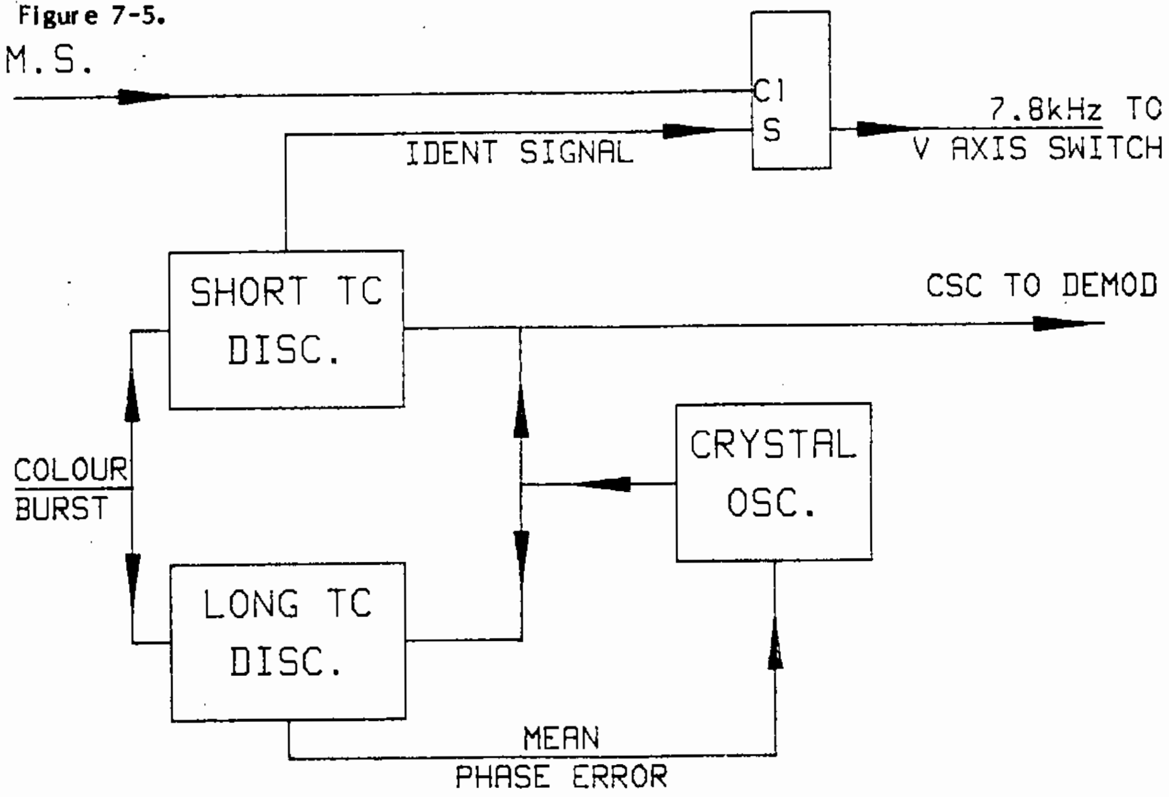


Figure 7-5. Regeneration of Reference CSC and VAS in a PAL Decoder.

7.5 THE PAL FOUR FIELD SEQUENCE

In the first package of this module, you encountered the two fields which go together to make a picture. The start of field one was defined as the point when the line sync reference and the field sync reference (leading edge of the first broad pulse) were coincident. This occurs every 2 fields or every 625 lines. With PAL signals the VAS waveform is at half line frequency. This means that if the VAS waveform is positive going at the start of a certain field, two fields or 625 lines later it will be negative going. It therefore takes four fields before the same relationship between line sync, field sync and VAS repeats itself.

The PAL television signal therefore has a four field sequence.

This excludes consideration of colour subcarrier to line sync relationship. This will be considered later.

7.6 DIFFERENTIAL PHASE DISTORTION WITH PAL.

We are now in a position to examine how differential phase distortion on the PAL system affects the transmitted picture. The effect is best considered by analysing the changes to the chrominance vectors.

Differential phase distortion rotates the distorted chrominance vector by some fixed angle, θ. The amount of phase shift on the vector depends solely on the amount of the distortion present at that particular luminance level and is independent of the chrominance phase.

Considering magenta again, the effect of θ° of differential phase is shown in Figure 7-6.

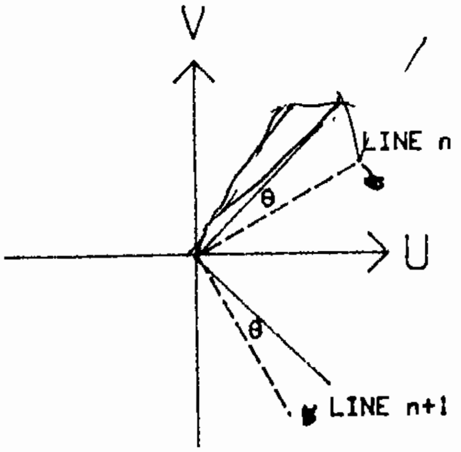


Figure 7-6. Effect of Differential Phase Distortion on Magenta.

CPQ19.

Describe the effect you would expect to see with the PAL system on a displayed Magenta if 24° of differential phase distortion were present. If you are in the slightest doubt about your answer to this question, sketch a vector diagram for magenta showing the normal and distorted vectors and then add to your diagram the resulting vector after the demodulator V axis switch operation has taken place.

one line Too blue
one line Too Red.

The question you have just attempted asked for the effect on a displayed picture. You can now check your answer by turning to the Practical Unit and undertaking experiment **COD 8.**

7.7 HANOVER BARS

The effect of differential phase distortion on Magenta was to make the magenta too blue on one line and then too red on the next. Brightness errors would also result and these would be most noticable to the viewer. The alternate lines however are as laid down during one of the two interlaced fields that make up a picture. The same process will occur on the other fields, producing two lines of blue-magenta and two lines of red-magenta.

The lines produced by a differential phase error on the displayed picture consisting of two lines of one hue followed by two lines of another hue are known as HANOVER BARS.

If the picture is viewed from a normal viewing distance, the Hanover Bars produced by differential phase distortion are less noticable. This is because the low resolution of the eye to colour changes causes the human eye and brain to average these two colours. The system would be improved, particularly for close viewing, if the averaging could be done electronically.

7.8 THE DELAY LINE PAL DECODER PRINCIPLE

If a decoder is to be modified to average the colours on two adjacent lines it has to have some means of storing the chrominance information from one line until the same time on the next line, when averaging can then take place. The method of storage used by such a decoder is a one line delay. The modified decoder containing a one line delay is known as a Delay Line Decoder. The principle of operation of a delay line decoder is shown in Figure 7-7.

(This method of decoding is sometimes referred to as PAL-D as opposed to the conventional or simple decoding method known as PAL-S.)

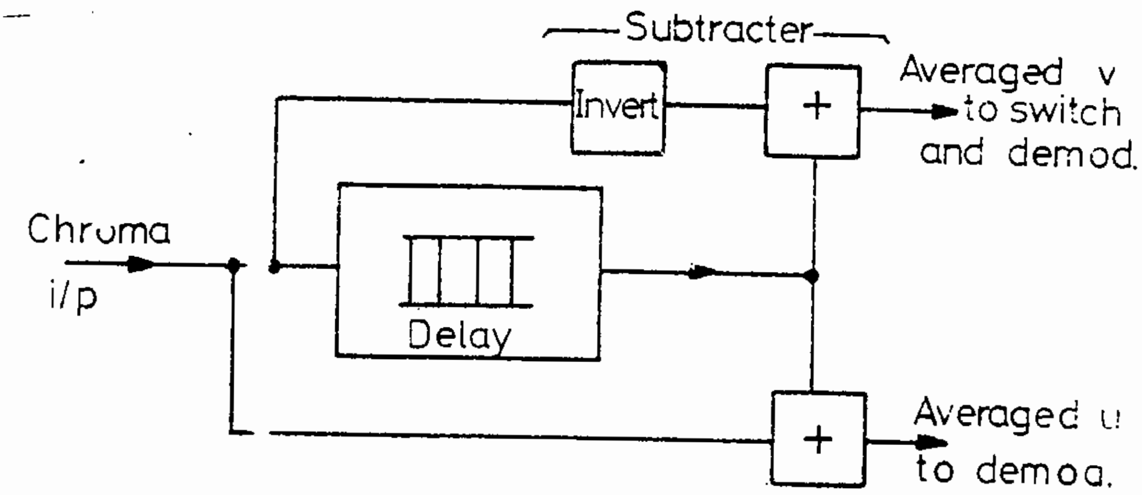


Figure 7-7. Operation of a Delay Line Decoder

7.9 METHOD OF OPERATION

Consider an undistorted magenta chrominance vector on line n as being $M(n) = U + jV$.

On line n + 1, the vector will be $M(n + 1) = U - jV$.

If the signal on line n is delayed by one line and then added to the signal on line n + 1, the result will be

$$M(n) + M(n + 1) = U + jV + U - jV$$
$$= 2U.$$

If the output of this adder is now halved, the original U component has now been isolated and can be fed to the U demodulator for conversion into the (B - Y) colour difference signal.

CTQ20

Deduce the output produced by subtracting the chrominance signal on line (n + 1) from that on line n, i.e. $M(n) - M(n + 1) = ?$.

NOTE: The one line of delay produced by the delay line must be an integral number of cycles of subcarrier, and not 64.00 μseconds. If this is not the case, a phase error which is independent of the input signal will be introduced. This results in reduced colour difference signal outputs and crosstalk.

7.10 HUE ERRORS WITH PAL-D DECODER.

Differential phase distortion will rotate the vector. If a phase lag is introduced, the U component will be increased and the V component decreased on one line, but on the next line, the U component will be decreased and the V component increased.

This is shown in Figure 7-8.

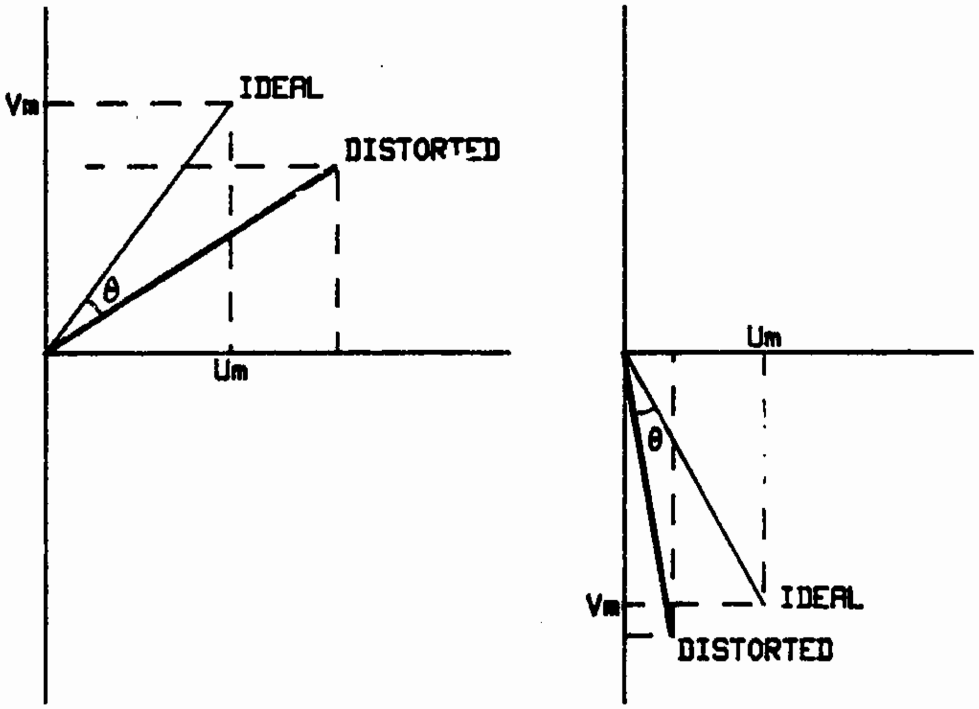


Figure 7-8. The effect of phase distortion on a magenta vector (a) line n(b) on line n +1.

The two chrominance vectors on alternate lines may be represented as:-

$$M(n) = (Um + x) + j(Vm - y)$$

$$\& \quad M(n + 1) = (Um - x) - j(Vm + y)$$

Averaging these two vectors gives

$$\frac{M(n) + M(n + 1)}{2} = \frac{Um + x + j(Vm - y) + Um - x - j(Vm + y)}{2}$$

$$= Um - j(y)$$

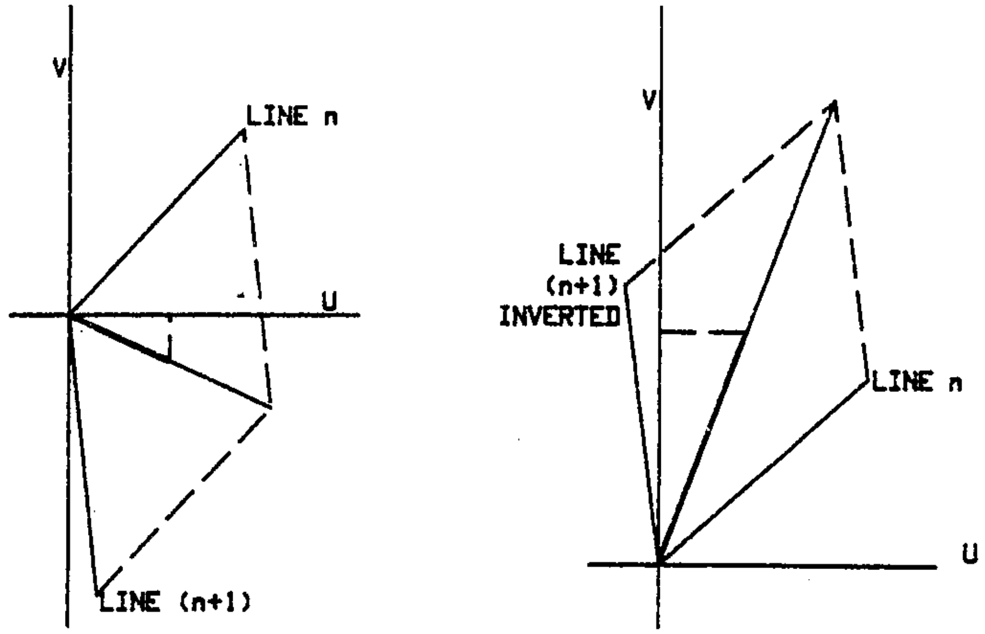
Similarly subtracting the two vectors gives $x + jVm$.

If these two signals, $Um - j(y)$ and $x + j(Vm)$, are now synchronously demodulated on the U and V axes, the outputs of the two demodulators will be the required colour difference signals Um and Vm.

7.11 SATURATION ERRORS WITH PAL-D DECODER

When the effect of phase distortion with delay-line de-coders was examined in the previous section, it was assumed that the errors in the U + V components were equal on both lines. This is not strictly the case and, as a result, saturation errors are produced from phase errors.
This can best be seen by again examining the chrominance vectors. The vectors produced if differential phase distortion is present were shown in Figure 7-8.

The action of the delay line stage in the decoder is in effect to add or subtract the vectors on two adjacent lines. The effect of this can be seen in Figure 7-9.



(a) (b)

Figure 7-9. (a) Addition, and (b) Subtraction of Chrominance Vectors in a PAL-D Decoder

This shows that both the U and V components have been reduced. This will result in lower amplitude colour difference signals after demodulation, hence de-saturation and reduction in brightness will occur.

It can also be seen that the resultant vectors for demodulation no longer lie on the U & V axes. This generally is of no importance since the demodulators only produce outputs proportional to their respective U or V components. It does mean, however, the phase of the reference demodulating subcarrier must still be correct otherwise Hanover Bars will result from the demodulation of this unwanted component..

7.12 PAL DECODER BLOCK DIAGRAM

The extra features required in a PAL decoder can now be added to the block diagram of Figure 4-7. The modifications required for the PAL system are,

(a) B.L.O. locked to mean phase of the burst using a long time constant on the error signal,

(b) V.A.S. waveform produced using a short time constant on the burst error signal.

(c) the V component switched by 180°on alternate lines using the regenerated V.A.S. waveform. (Alternatively the phase of the V modulator reference signal may be switched by 180°.)

(d) the inclusion of a delay line stage which in a broadcast monitoring situation may be switched out. (If a PAL-D decoder is operated in the SIMPLE mode, the gain of the undelayed chrominance signal must be increased by 6dB to compensate for the absence of signal from the delay line stage).

(e) provision of a colour killer. (The presence of the V.A.S. waveform may be used as an indication of the presence of a burst. The V.A.S. waveform can be rectified and used to enable the chrominance information. In the absence of burst, decoding is inhibited thus avoiding any high frequency luminance components of the monochrome signal being decoded as colour.)

A typical block diagram of a PAL decoder is shown in Figure 7.10.

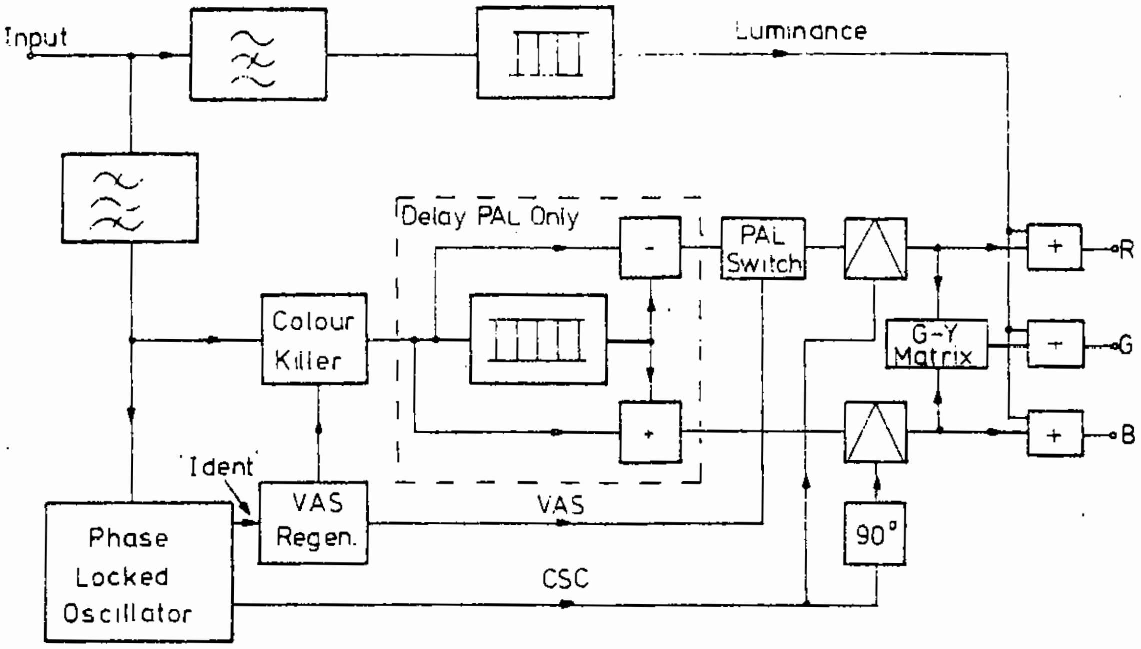


Figure 7-10. PAL decoder Block Diagram.

To verify the effects on a picture of differential phase distortion when decoded using a delay line decoder, turn to the practical unit and undertake the investigations **COD 9** and **COD 10.**

7.13 DIFFERENTIAL PHASE DISTORTION IN PAL DECODERS

The effects of differential phase distortion in the PAL system can now be summarised for both types of decoder.

(a) Simple PAL.

Differential phase distortion on a signal fed to a simple PAL decoder will produce Hanover Bars combined with brightness and saturation errors.

(b) Delay Line PAL.

In the absence of any distortion, a delay line decoder will isolate the U and V signals prior to demodulation. Phase distortion on the input signal will, however,

(i) eliminate the hue errors but still leave the displayed picture desaturated, and suffering from brightness errors,

(ii) not entirely isolate the U and V signals prior to demodulation, thus still necessitating the requirement for synchronous demodulation.

SECTION 8

CHOICE OF SUBCARRIER FREQUENCY

SECTION 8. CHOICE OF SUBCARRIER FREQUENCY.

8.1 Factors affecting subcarrier frequency

8.2 Brightness errors

Fig. 8-1 Effect of subcarrier on mean luminance level

8.3 Dot Patterning caused by subcarrier

Fig. 8-2 Effect of dot patterning

CPQ 21

PRACTICAL **COD 11**

Fig. 8-3 NTSC Chrominance dot patterning

CPQ 22

PRACTICAL **COD 12**

Fig. 8-4 Affect of the PAL switch on chrominance signals which are
(a) predominantly V
(b) predominantly U

8.4 The PAL Subcarrier Frequency

8.5 The PAL Eight Field Sequence

8.6 Bruch Blanking

Fig. 8-5 Field Sync Waveform showing Bruch Blanking

8.7 Luminance to Chrominance Crosstalk

PRACTICALS **COD13** & **COD 14.**

8. CHOICE OF SUB-CARRIER FREQUENCY.

8.1 FACTORS AFFECTING THE CHOICE OF SUBCARRIER FREQUENCY

In order to minimise the visual effect of the subcarrier, it should be as high in frequency as possible, bearing in mind that the chrominance sidebands should still line within the luminance spectrum. What are the effects of adding the chrominance signal to the luminance?

8.2 BRIGHTNESS ERRORS

Any signal which has a high frequency sine wave added to it will suffer an increase in brightness from its true value. This is due to the non-linearity of the tube.

Consider a steady luminance d.c. signal with a superimposed chrominance signal. The effect can be seen in Figure 8-1.

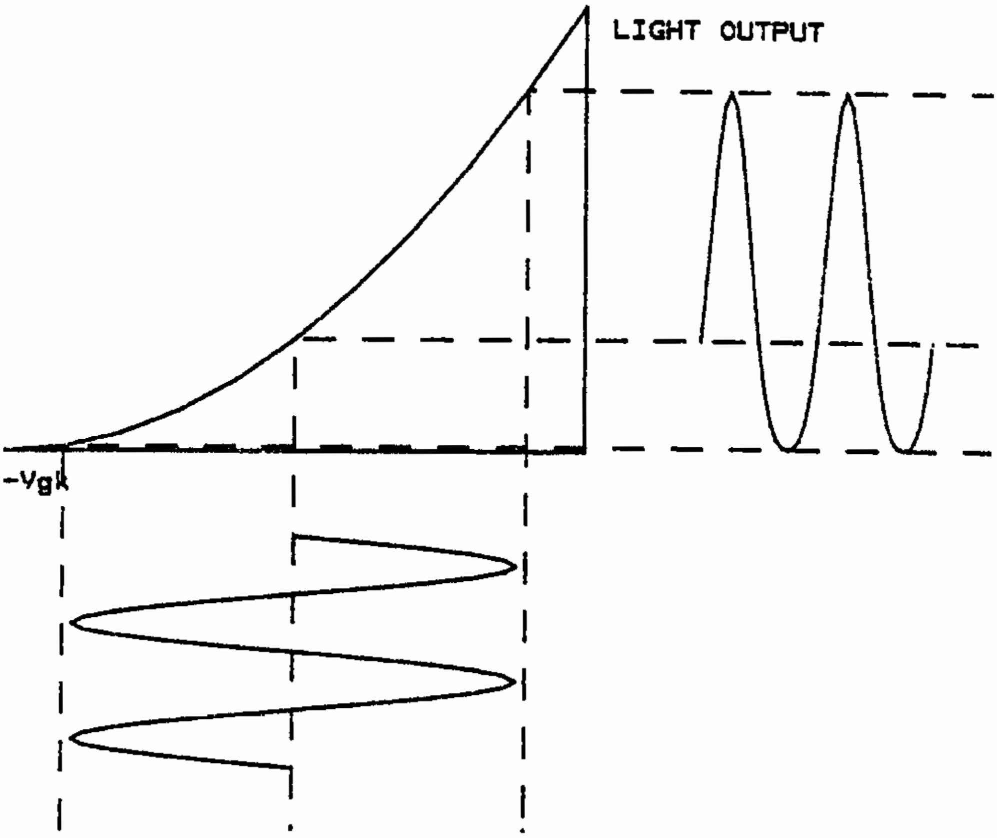


Figure 8-1. Effect of Subcarrier on Mean Luminance Level.

The light output from the tube is not exactly sinusoidal, but its visual effect is very close to that of a slightly higher mean luminance level with a superimposed sine wave. The long term or mean brightness error will be the same whatever subcarrier frequency is used, but what about the short term errors?

8.3 DOT PATTERNING CAUSED BY SUBCARRIER

As a line is scanned on the picture display tube, the subcarrier superimposed on the luminance signal will be treated as if it were a high frequency luminance component. The effect this brightness modulation produces will depend on:-

(a) the viewing distance, and

(b) the interfering subcarrier frequency.

We have no control on the viewing distance, but, provided the chrominance frequency is high enough, the eye will not resolve it at an average viewing distance in sufficient amplitude to find it objectionable.

For an average natural scene, the degree of saturation is usually fairly low so the amplitude of the colour difference signals and hence, the chrominance signal is also low. A subcarrier notch filter in the luminance chain would also reduce the effect, but this would be at the expense of loss of fine detail.

How does the subcarrier frequency to line frequency relationship affect the interference? Consider the result of having the subcarrier at an exact multiple of line frequency, e.g. 4.00 MHz, which is 256 x line frequency.

This would mean that, at any time, the phase of the subcarrier would be exactly the same as it was exactly one line earlier. For scenes with a high chrominance component, this would produce a pattern of vertical dark and light lines and shown in Figure 8-2.

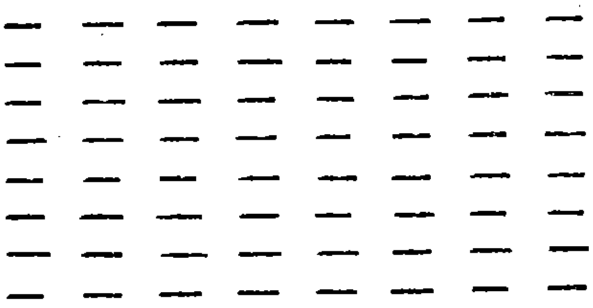


Figure 8-2. Effect of Dot Patterning

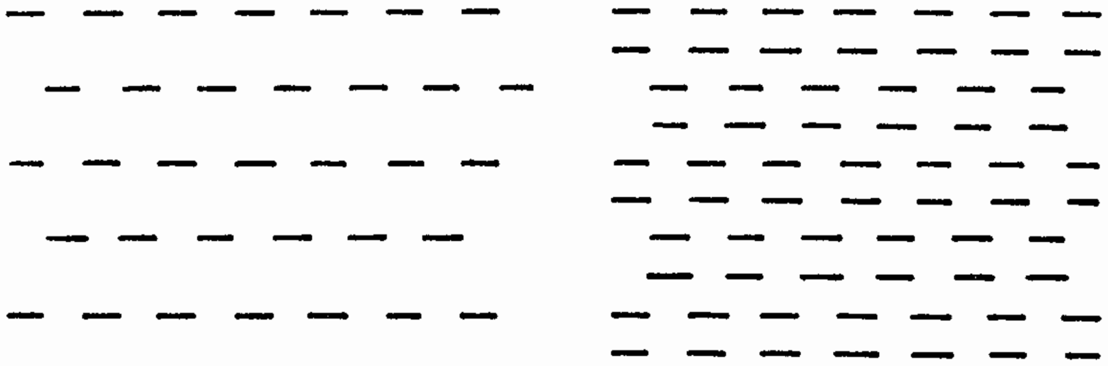
CPQ 21.

What effect would the chrominance produce on the luminance output if its frequency was made an odd multiple of half line frequency. It may help you to first consider a very low odd multiple, e.g. ($^3/2$) x line frequency, for one field and then add the effect of the interlaced field.

To varify your result, turn to the practical unit and undertake the investigation number **COD 11.**

This is the method adopted by the NTSC system. The actual multiple chosen is ($^{567}/2$) times line frequency. For a 625 line 50Hz NTSC system, the subcarrier frequency would be 4.4296875 MHz . The British PAL system uses a modification to this, but you will encounter this frequency later when dealing with Waveform Generation and the Natlock system.

What effect would the PAL system have if this frequency relationship were adopted? Using an odd multiple of half line frequency results in a chrominance dot pattern as shown in figure 8-3. Interlacing the two fields causes the dot pattern to appear in pairs.



(a) (b)

Figure 8-03. NTSC Chrominance Dot Patterning.

(a) for one field (b) for one interlaced picture

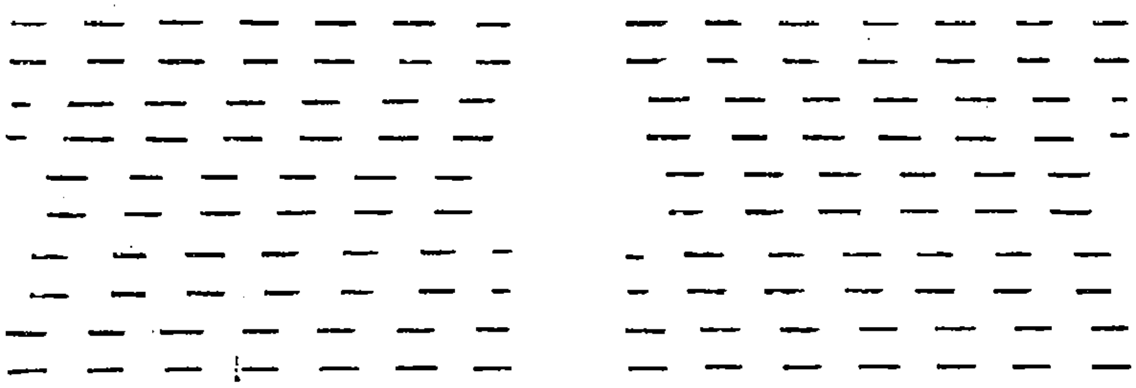
The PAL system inverts the phase of the V component on alternate lines as laid down. Consider a colour such as red or cyan. Referring to the table in Figure 4-2 it can be seen that these two colours have a large V component and only a small U component.

CPQ22.

Draw the pattern which results from a chrominance signal lying on the V axis. Include the effect of interlace.

Verify your result by undertaking the investigation **COD 12** in the practical unit.

The PAL system overcomes this feature by modifying the relationship of subcarrier to line frequency by including a factor of 1/4. This would make the relationship ($^{1135}/4$) or $283^3/4$ times line frequency. Figure 8-4 shows the effect of having an odd number of quarter cycles of subcarrier in each line. Figure 8-4(a) is the patterning effect produced by a chrominance signal with a very small V component (e.g. Yellow). Figure 8-4(b) shows the effect produced after the PAL switch has inverted the phase of the V component of the chrominance signal produced from a colour which has a high V component.



(a) (b)

Figure 8-4. Effect of PAL switch on chrominance signals which are
(a) predominantly U (e.g. yellow)
(b) predominantly V (e.g. cyan)

8.4 PAL SUBCARRIER FREQUENCY

The effect of the PAL switch is to change the direction of the diagonal line patterning on signals which have a large V component.

Using a chrominance frequency which has a quarter of a cycle phase shift per line in the 625 line per picture standard results in a quarter of a cycle phase advance on the same line in the next picture. This results in the effect of the diagonal lines running slowly down the screen.

The final modification to the frequency used is the addition of 25Hz (or 1/625 x line frequency). This is known as the PRECISION OFFSET. The effect of this is to invert the phase of the subcarrier on the equivalent point on the next field. This results in its brightness modulation being averaged over several pictures to zero.

The final frequency of PAL subcarrier is:-

$$(283.5 + .25 + 1/625) \times 15.625 \text{ kHz or } 283^3/4 \text{ f} + 25\text{Hz}.$$

$$= \underline{4.43361875} \text{ MHz}$$

8.5 THE PAL EIGHT FIELD SEQUENCE

The basic monochrome signal has a sequence which repeats itself every two fields. The basic PAL system however, incorporates V axis switching at half line frequency, so taking four fields to repeat its sequence. For most requirements the PAL system can be considered as repeating in a four field sequence, but this does not take into account the subcarrier frequency.

From examination of the derivation of the PAL subcarrier frequency, it is found that it takes eight fields before any line position to subcarrier phase relationship repeats itself. This is due to the quarter line frequency component. The British PAL Television system therefore strictly speaking has an eight field repetition sequence.

8.6 BRUCH BLANKING

It is necessary that the burst is removed for a short time during the field blanking interval. Although all present day decoders could easily cope with the burst being blanked for a constant set of lines, there was some doubt as to whether very early colour receivers could lock their carrier oscillators sufficiently quickly following the re-appearance of the burst.

As an incorrectly locked oscillator will lead to phase errors, and even a possible loss of regenerated V-axis switching signal, it was decided to try and eliminate the problem. The work was carried out by Dr. Bruch, a member of the original committee on PAL. The result of this is that the burst is always blanked for 9 lines, however the actual 9 lines are different on each of the four fields. This results in the first and last bursts of each field always having the same instantaneous phase, i.e. that which corresponds to a normal V-axis polarity.

Some modern equipment, e.g. video cassette recorders, actually now make us of Bruch Blanking to identify the PAL sequence.

The video waveforms around the field sync interval with Bruch Blanking are shown in figure 8-5.

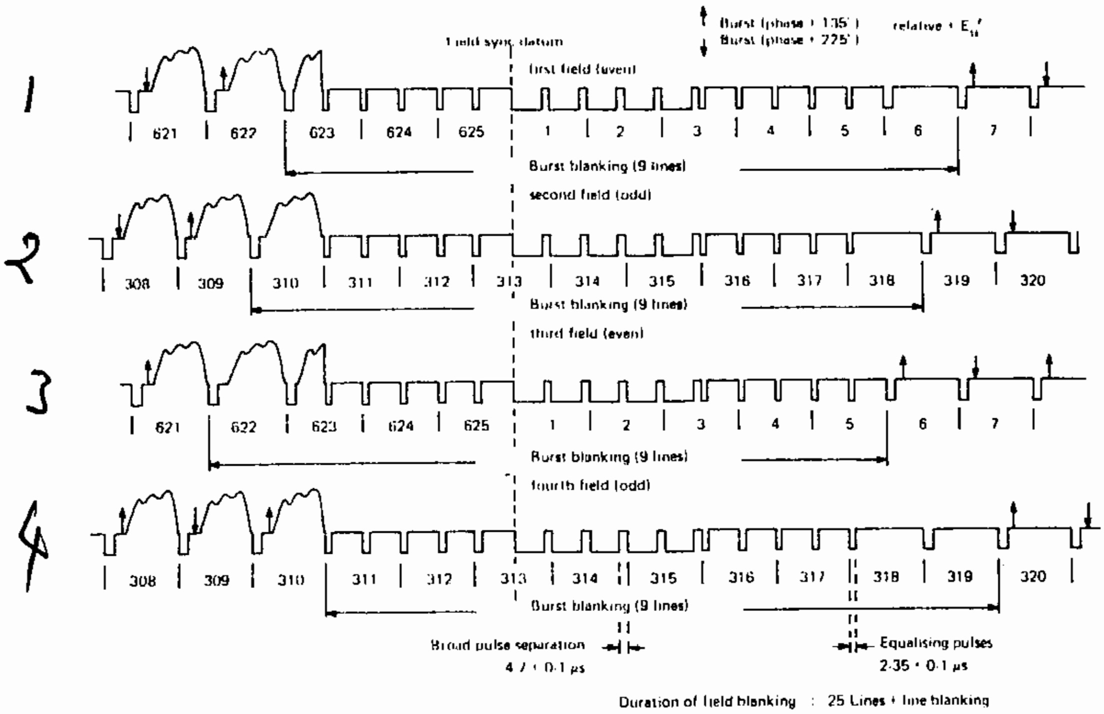


Figure 8-5. Field Sync Waveform Showing Bruch Blanking

8.7 LUMINANCE TO CHROMINANCE CROSSTALK

Another side effect of the actual chrominance frequency used is that of crosstalk. Any luminance signal lying within the chrominance spectrum will be decoded as colour.

A luminance signal which has a frequency of 4.33 MHz will be decoded as chrominance producing colour difference signals at about 100kHz. Such a signal could be produced from a fine check material (eg. a mans jacket). If the subcarrier phase relationship on adjacent lines were the same, or very close, the effect of this would be a strongly coloured almost stationary interfering pattern. The quarter cycle and precision offset help to reduce this effect.

A future development being considered to overcome this problem is to remove the high frequency luminance component from the coded video signal and transmit it separately.

The concluding investigations **COD 13 - COD 14** in the practical unit will demonstrate the effect of these two offsets both on the dot pattern and on the interference produced from luminance crosstalk.

G.G. Winter/GT/VC/PALCOD
17th February 1982

SECTION 9

SUMMARY